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Grain Sorghum Storage

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SUMMARY

To find what types of structures and what storage practices are most successful in maintaining the quality of grain sorghum stored on the farm, a cooperative study was carried on from 1939 to 1947 by the Agricultural Research Administration and the Production and Marketing Administration of the United States Department of Agriculture and the Kansas Agricultural Experiment Station.

In a preliminary survey made in parts of Kansas, Oklahoma, Texas, and New Mexico in the spring and summer of 1939, storage facilities on farms were found to be generally inadequate. About one-fourth of the grain sorghum surveyed was stored outdoors, either in piles of threshed grain or in stacks of headed grain. Many of the storage structures in use were not in good condition. Many farmers were having trouble from grain heating, and a majority reported some trouble from insect infestations.

Tests at the Fort Hays Branch Experiment Station and at the Commodity Credit Corporation bin site at Hutchinson, Kans., indicated that the maximum moisture content of grain sorghum for safe year-round storage in a tight bin is about 13 percent under Kansas conditions. Grain of higher moisture content is likely to be damaged by growth of molds and

¹The authors report the results of a study of the storage of threshed grain sorghum in farm-type structures, which was carried on with special research funds from 1939 to 1947. This work was performed partly under an allotment from the Special Research Fund authorized by Title I of the Bankhead-Jones Act of June 29, 1935. The project was initiated in 1939 by three bureaus of the United States Department of Agriculture—Agricultural Engineering, Agricultural Economics, and Plant Industry, also the Kansas Agricultural Experiment Station. The Agricultural Adjustment Administration partici-

heating; and the higher the moisture content becomes the greater will be the probability of damage. Grain with 20 percent moisture became hot within 1 week after being binned in the latter part of November. Grain with 15 percent moisture, binned late in fall or early in winter, was free from visible damage until a period ranging from April to June. The loss of germination and the increase in fat acidity, however, were greater than in grain with less than 13 percent moisture.

In storing grain with high moisture content clean preparation was found to be important. Excessive mold developed in locations in the bin where there was much cracked grain and foreign material; in locations where the grain was clean, it stored in relatively good condition.

Nine designs of wind-assisted bin ventilation were tested to determine their effectiveness in removing excess moisture from the grain. The force of the wind was utilized to cause air movement by suction cowls to draw air through the grain and by pressure cowls to force air through it. The pressure cowl was found to be more effective than the suction cowl. The type of bin considered most practical for use on farms in dry climates, provided the depth of grain is determined according to its moisture content, is one with a wind-pressure cowl connected with an air chamber under a perforated bin floor. In this type the air moves upward through 2 to 6 feet depth of grain over the floor. The damper the grain, the less should be put in the bin.

Removal of excess moisture by power ventilation with unheated air was successful in warm weather under normal Kansas conditions. This method was effective in promptly reducing the temperature of heating grain, but removal of moisture was slow at winter temperatures and also at summer temperatures when the air humidity was unusually high.

To determine the relation of drying rate to the temperature and humidity of drying air, a series of laboratory tests was made with heated air. Results indicated that heated air may be more satisfactory than unheated air.

In a small-scale test of the effect of moisture content on the quality of sorghum grain silage, 17 to 38 percent moisture was found to have little

pated in the project in an advisory capacity from the beginning. The Commodity Credit Corporation and later the Grain Branch of the Production and Marketing Administration loaned sorghum grain and bins for the study. The Bureau of Entomology and Plant Quarantine entered formal participation in the project in 1941.

Following some changes in organization, the parties to the cooperative agreement in the fiscal year 1947 were the Bureau of Plant Industry, Soils, and Agricultural Engineering, the Bureau of Entomology and Plant Quarantine, and the Grain Branch of the Production and Marketing Administration, for the United States Department of Agriculture; and the Kansas Agricultural Experiment Station.

Work on the project was carried on at the Fort Hays Experiment Station, Hays, Kans., until 1941, when it was moved to the Commodity Credit Corporation bin site at Hutchinson, Kans. At Hays, the work was under the immediate supervision of W. R. Swanson, assistant agricultural engineer, for the Bureau of Agricultural Engineering, and L. C. Aicher, superintendent of the Fort Hays station, for the Kansas Agricultural Experiment Station. At Hutchinson, the engineering phases of the work were under W. R. Swanson until June 1943, and under E. R. Gross, associate agricultural engineer, from November 1943 to October 1946. The engineering phases of all grain storage investigations, in which this investigation was included, were supervised by H. J. Barre, senior agricultural engineer, until 1943 and from that time until the project was closed in June 1947, by W. V. Hukill. The final report of the engineering phases of the project was compiled by C. K. Shedd from previous progress reports and records of experiments. The entomological studies were made by H. H. Walkden, assisted by R. B. Schwitzgebel, agent, both of the Bureau of Entomology and Plant Quarantine.

effect upon its protein, fat, or carbohydrates. The higher moisture content resulted in higher acidity. The quantity of moldy silage near the surface was greater at 17 and 19 percent than at higher rates. The apparent quality of the unspoiled part of the silage was best at between 19 and 24 percent moisture.

Observations were made of the insects attacking grain sorghum stored in farm-type bins at Hutchinson during the period 1941 to 1946, and tests were made to determine the necessary dosage of various fumigants for their control. Six species of insects commonly attacking stored grain were found infesting grain sorghum. The development of infestation showed the same trends as in wheat; namely, peak populations were built up late in summer, during August and September.

For the control of insect infestation it was found that twice the dosage of fumigant was required for stored grain sorghum as for wheat under the same conditions.

If grain sorghum is to be stored during the summer following harvest it should be inspected frequently beginning in July. If 1 or more weevils or 15 or more bran bugs per quart of grain are found, the grain should be fumigated immediately. For long-time storage (more than 1 year) it should be fumigated every year in August or early in September. The safety precautions given on page 27 should be observed in the application of fumigants.

PRODUCTION AND STORAGE PROBLEMS

Farmers generally have experienced more storage difficulty with threshed grain sorghum than with any other grain crop except corn. Problems arise from a number of factors, including the nature of the crop itself and the climatic conditions in the main areas of production.

Grain sorghum differs from wheat and other small grains in that the stalks are still green when the grain is mature and may contain up to 60 percent moisture. Also grain sorghum matures in fall, when weather conditions are not so favorable as in midsummer for drying the crop in the field. Even with good management in harvesting and threshing, it is difficult sometimes to deliver grain from the combine or thresher at a moisture content low enough for safe long-time storage in tight bins.

Insect infestation is another important problem in long-time storage. A large part of the grain sorghum acreage in the United States is in areas where the climate is warm enough to make conditions favorable for the activity of insects in stored grains.

Grain sorghum (including kafir, milo, and feterita) is the most important feed grain crop in the southern Great Plains region. The average area annually harvested for grain in the United States in 1934-43 was 4,886,000 acres.² Of this total, Texas had 2,466,000 acres; Oklahoma, 717,000; and Kansas, 915,000. More than 80 percent of the total crop was produced in these three States, but grain sorghum is important in other States where dry periods in summer are likely to limit corn production.

Both acreage harvested and the yield fluctuate widely from one year to another. Generally about half the crop is harvested for grain, but in a poor crop year when feed is short more of the crop is harvested for forage. For example, in 1934, a drought year in the Plains region, 2,396,000 acres were harvested for grain and 8,182,000 acres for forage, while in 1944

² UNITED STATES DEPARTMENT OF AGRICULTURE. AGRICULTURAL STATISTICS, p. 65. 1946.

the acreage harvested for grain totaled 9,104,000, compared with 3,193,000 acres for forage. The production of grain in 1934 was, in round numbers, 19 million bushels; in 1944 it was 182 million bushels; and in 1945, about 96 million bushels.

Such wide fluctuations in feed production make it difficult to follow a well-planned program of livestock production. If an adequate part of the high production of good crop years could be carried over for feed in poor crop years, it would tend to stabilize livestock production and farmers' income in the Great Plains region.

PRELIMINARY SURVEY

A survey of grain sorghum storage on farms in parts of Kansas, Oklahoma, Texas, and New Mexico was made in March and April 1939, and the same storages were revisited in June of that year. The purpose was to get information on the structures and practices being used and the difficulties experienced by farmers in storing grain sorghum. Typical areas to be surveyed (fig. 1) were selected with the advice of the Agricultural Adjustment Administration and other agencies and individuals as follows:

Area	In the vicinity of—
South-central Kansas	Eldorado
Southwestern Kansas	Garden City and Liberal
Eastern New Mexico	Clovis
Northern Texas	Lubbock and Memphis
Western Oklahoma	Canute



FIGURE 1.—Approximate location of Hays and Hutchinson, Kans., where grain sorghum storage experiments were carried on from 1939 to 1947; and of Kansas, New Mexico, Texas, and Oklahoma cities near which preliminary survey work was done in 1939.

On each farm included in the survey, information was obtained on the method, time, and conditions of harvesting and threshing, and a description of the storage structure was recorded. At each visit a sample of the grain was taken.

On the first trip, 81 samples were taken on 60 farms. A large part of the grain was in good condition even though about one-quarter had been stored outside with little or no protection from weather. Only 6 samples graded "Sample Grade." Only 8 samples had

as high as 14 percent moisture and none as high as 15 percent. The average moisture content for different storage methods was:

	Percent		Percent
Threshed:		Headed:	
Stored in inside bin	12.0	Stored inside	11.8
Stored outside	13.1	Stored outside	12.2

The dry condition of the grain is accounted for by the fact that the weather was unusually dry during the fall and winter of 1938-39. At the time of the second inspection only about one-third of the grain remained and there was little damage in it. The grain stored outside was generally contaminated with dust, and some insect infestation was observed in outside storage, although none of the samples graded "weevily."

Although farmers had little difficulty in storing grain sorghum during 1938-39, more than half those interviewed reported bin heating in previous

years. Six of the bins inspected had ventilators of different kinds for the purpose of removing moisture from the grain.

Some good storage structures were found in this survey, but in general the farm storage facilities were inadequate. Many of the structures were old and had not been maintained in good condition. More than three-fourths of those examined had some structural defect, such as roof leak, leaks around windows or doors, structural failure of wall or floor, or inadequate foundation. Most of the structures were of frame construction with outside walls double covered. A few were 1,000-bushel steel bins. Typical storages are shown in figures 2 to 5, inclusive.



FIGURE 2.—Good farm granary near Benton, Kans. March 16, 1939.



FIGURE 3.—Farm grain bin near Liberal, Kans., in an unsatisfactory condition. March 20, 1939.



FIGURE 4.—Outside stacks of headed grain sorghum near Littlefield, Tex. March 30, 1939.



FIGURE 5.—Threshed grain sorghum stored outside near Clovis, N. Mex. March 20, 1939.

A majority of the farmers interviewed reported some trouble with insect infestations in stored grain sorghums. Stocks of this grain, however, were usually low late in summer, when grain insects are most active. Dry grain (probably 9 percent moisture) was considered reasonably safe from insect attack. A few farmers had fumigated, but the majority were not familiar with this practice.

WEATHER CONDITIONS IN KANSAS, 1939-46³

1939 was the third warmest and fifth driest year Kansas had experienced in the 53 years that State-wide records had been kept. The average precipitation for the eastern third was 26.54 inches; the middle third 20.91; the western third 12.79; and for the State as a whole, 20.08, which was 6.35 inches below normal. A prolonged drought, the most severe on record for

³ Abstracted from United States Weather Bureau annual summaries.

the time of year, occurred from the latter part of August until the closing days of December.

1940 averaged nearly normal in temperature and precipitation, but great extremes of temperature occurred and there was a severe drought in July. The outstanding features of the year's weather were the abnormal cold of January, the exceptional heat and drought of July, and record-breaking low temperatures early in November.

1941 was, with the exception of 1915, the wettest known in Kansas since the State-wide record was begun in 1887, and the extent of cloudiness was unusual. Spring months were favorable for wheat and corn, and there was little damage from hot or dry summer weather. Harvesting operations in June and again in the fall were hampered by wet weather.

1942 was one of the most favorable years for crops known in Kansas history. Average precipitation was the fifth greatest in a 55-year record and, combined with that of the wet year preceding, made the heaviest precipitation ever known to fall over the State in two successive years. No damaging droughts or excessively hot spells occurred. Snowfall averaged 25 percent above normal. Spring months were ideal for crops. Wet weather in June delayed wheat harvest, but July proved favorable for its completion. Moisture conditions were good in the fall. An early frost the last week of September killed a large part of the grain sorghums before they had matured. (None of this crop was used in storage experiments.)

1943 rainfall was below normal in practically all parts of Kansas, except the southeastern counties, and it was a year of temperature extremes, with one of the hottest summers on record and unusually low temperatures in January. Rainfall was deficient the first 4 months. Heavy rains occurred over most of the State in May and June, but July and August were abnormally hot and dry and dry weather continued through September, October, and November.

1944 was the wettest year of record in Kansas except 1915. The average precipitation over the eastern third was 47.13 inches; the middle third, 37.79 (Hutchinson, 46.97); the western third, 27.54; and for the State as a whole, 37.47, which was 10.61 inches above normal and about 50 percent more than in 1943. Record-breaking precipitation occurred during the first 4 months. May was warm and sunshiny. Good crop-growing weather prevailed during the summer. The fall was comparatively mild and dry, but December was exceptionally wet and cold.

1945 began with comparatively mild, wet, and excessively cloudy weather, which extended through March. Above-normal rainfall continued in the eastern half into July, but by that time the western part was becoming dry. Excessively hot weather in August and September caused general deterioration of corn and grain sorghums. October and November were mild and dry. Average precipitation for the State was 30.20 inches, which was 3.29 inches above normal. Snowfall was 50 percent above normal.

1946 precipitation was sufficient over most of the eastern two-thirds and abnormally heavy over the western third. Snowfall was the third lightest on record. Weather was generally favorable for all crops except corn, but the average temperature for the year was 2.8° F. above normal. The first 4 months averaged the mildest on record. May was wet and cold. June, July, and the early part of August were abnormally warm and in many parts of the State precipitation was deficient. The rest of the year was mild, with ample rainfall.

INVESTIGATIONS AT THE HAYS AND HUTCHINSON, KANS., AND AMES, IOWA, STATIONS

The grain bins for research on grain storage at the Hays station are shown in figure 6; those at Hutchinson in figure 7. A large part of the facilities at both stations was used for wheat storage studies. The number

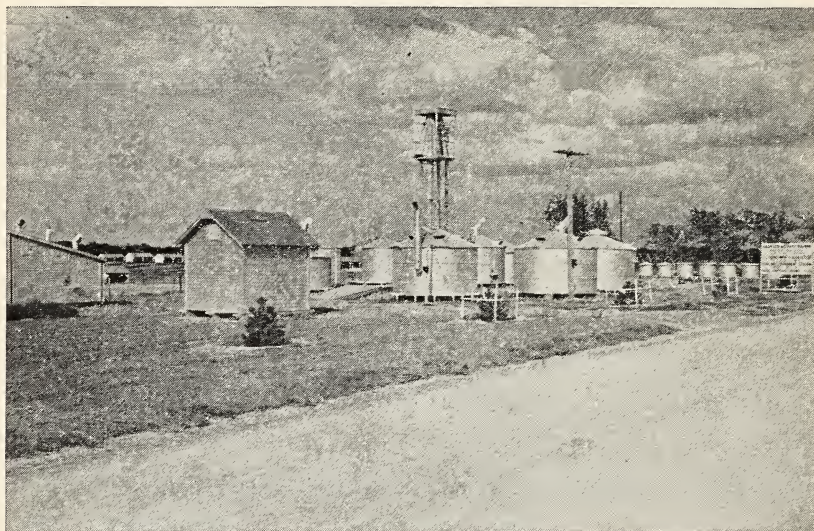


FIGURE 6.—Experimental bins at the Hays station—bin No. 7 in the center front; small bins Nos. 27 to 33 at the right. September 16, 1939.

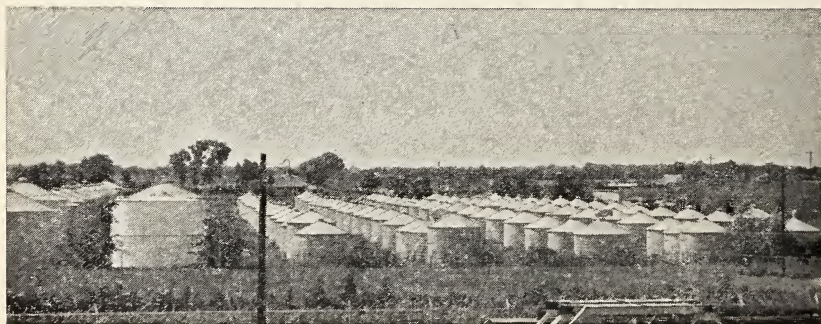


FIGURE 7.—Experimental bins at Hutchinson. June 1941.

TABLE 1.—*Number of lots and total quantity of grain sorghum stored each year at the Hays and Hutchinson, Kans., stations*

Year	Lots	Quantity stored	Crop	Year	Lots	Quantity stored	Crop
		<i>Bushels</i>				<i>Bushels</i>	
1939...	20	5,700	1938 and 1939.	1942...	8	8,000	1941.
1940...	5	3,500	One lot 1938, rest 1940.	1944...	6	3,600	1944.
			1941.	1945...	6	5,500	1945.
1941.	4	3,200		1946...	2	1,800	1945.

of lots and total quantity of grain sorghum stored each year are shown in table 1.

TYPES OF BINS

The bins used in these studies were mostly cylindrical steel of two sizes, 500- and 1,000-bushel capacity. The 500-bushel bins were 10 feet in diameter, walls 8 feet high; and the 1,000-bushel bins were 14 feet in diameter, walls 8 feet high. A plain tight steel bin, that is, one with no provision for aeration of the grain, is shown in figure 8. Prefabricated bins of this type are used in considerable numbers by farmers. The walls and roof are made of galvanized steel sheets bolted together on the job. The walls rest on a ring of concrete blocks, and a galvanized sheet-steel floor rests on an earth fill crowned a little above the level of the top of the foundation blocks. Five small bins of sheet metal construction 40 inches in diameter and 36 inches high were used for check tests. Many of the bins used in these studies were provided experimentally with various means of aerating damp grain, as will be described in the discussion of wind-assisted and power ventilation.



FIGURE 8.—Plain steel bin with no provision for aerating the grain.

GRAIN MOISTURE CONTENT AND GRAIN TEMPERATURE

Rapid or severe damage to grain in storage can usually be charged primarily to high moisture content. In the absence of insect infestation, heating of grain in the bin is caused by excessive respiration of the molds on the grain and of the grain kernels themselves and also by fermentation of the grain. Both processes are active in moist grain at summer temperatures and both produce heat, which if not dissipated will cause heating of the grain and rapid spoilage. At winter temperatures, grain may have a somewhat higher moisture content without heating, but if heating once starts it may proceed at a rapid rate even in cold weather. Severe molding may take place in a period of several months in grain that is not moist

enough to heat. Some mold growth may occur in winter, but it is much more rapid in summer. Insects are most active at grain temperatures above -65° F. and of little importance at grain temperatures below 40° . For all these reasons, it is desirable to store grain as dry as possible and to keep the temperature as low as possible.

In reports of previous wheat storage studies, Kelly et al. state: ⁴

In tests with combined wheat, where the wheat moisture content was uneven, it was found that the length of safe storage did not depend upon the average moisture content for the bin but upon the highest wheat moisture content in the bin.

The grain sorghum storage lots studied at Hays and Hutchinson were all well mixed, with the exception of a lot that was artificially dried, but it is assumed that the results with varying moisture contents within the bin would correspond with the results observed with wheat. The results obtained in storage of grain sorghum of different moisture content in tight unventilated bins at Hays in 1939 and 1940 are recorded in tables in the Appendix, as follows:

Bins 1, 11, 27, 28, 30, and 31—tables 4 and 5.

Bins 1, 24, 27, 28, 30, and 31—tables 6 and 7.

Bin 1—tables 9 and 10.

Lots with less than 12 percent moisture stored without observed damage. Lots with 13.9 percent or more moisture all turned sour or musty in less than 1 year of storage. Heating occurred if the moisture content was 15 percent or more. When grain containing 20 percent moisture was placed in storage late in November, heating occurred within 1 week. Grain containing 15 percent moisture placed in storage at the same time did not heat until the following June.

Between November 29, 1945, and January 11, 1946, eight 1,000-bushel bins at Hutchinson were filled with grain sorghum of various moisture contents for the purpose of studying the effect of moisture on storage. Initial grade samples were taken on January 28, 1946, and final grade samples on July 17, 1946. This series consisted of two bins in each of the following moisture ranges: (1) 10.6 percent; (2) 11.9 percent to 12.1 percent; (3) 12.6 percent to 12.8 percent; and (4) 14.8 percent to 15.0 percent. Analyses of these samples are recorded in table 2.

The apparent decrease in cracked grain and foreign material was probably due to differences in the techniques that were followed in taking or analyzing the samples. In three bins (3-14, 2-12, and 2-14) this decrease improved the commercial grade from No. 2 to No. 1. The test weight increased 0.5 pound in bin 2-16 at a point where it changed the grade from No. 3 to No. 2. The change in test weight in different bins does not appear to be definitely correlated with moisture content, although the largest increase was in the driest grain.

Fat acidity increase was variable in lots containing from 10.6 to 12.8 percent moisture, but the change does not appear to be correlated with moisture content in this range. In the two lots containing 14.8 and 15.0 percent moisture, however, the increase in fat acidity was approximately twice as great as in the drier lots of grain, and this appears to be a consequence of deterioration due to high moisture content. Likewise, the decrease in germination was marked in the two high moisture lots. The

⁴ C. F. KELLY ET AL. WHEAT STORAGE IN EXPERIMENTAL FARM-TYPE BINS. U. S. Dept. Agr., Cir. 637. p. 138. 1942.

TABLE 2.—*Effect of moisture content on storage of grain sorghum, 1946*

Bin No.	Date sampled	Grain sorghum grade ¹	Test weight Pounds	Moisture Percent	Dockage Percent	Odor	Foreign ² material Percent	Fat acidity Units	Germination Percent	Date emptied	Observations when emptied
2-16	{ Jan. 28	No. 3 Y. M.	52.8	10.6	0.6	O.K.	5.5	23	52	Aug. 9	No spoilage.
	{ July 17	No. 2 Y. M.	53.3	10.6	.3	.. do ..	2.6	37	61		
	{ Jan. 28	No. 2 Y. M.	53.1	10.6	.7	.. do ..	6.0	25	54	Aug. 17	Do.
3-15	{ Jan. 28	No. 2 Y. M.	54.5	10.6	.2	.. do ..	3.6	31	58		
	{ July 17	No. 2 Y. M.	57.6	11.9	.7	.. do ..	4.9	19	61	July 26	Do.
	{ Jan. 28	No. 2 Y. M.	57.9	11.8	.3	.. do ..	2.5	30	62		
4-13	{ July 17	No. 1 Y. M.	57.6	12.1	.2	.. do ..	3.4	24	53	Aug. 9	Do.
	{ Jan. 28	No. 1 Y. M.	57.6	12.1	.1	.. do ..	1.5	32	68		
	{ July 17	No. 1 Y. M.	57.5	12.6	1.4	.. do ..	4.4	28	54	Aug. 17	Do.
2-12	{ Jan. 28	No. 2 Y. M.	56.8	12.6	.6	.. do ..	2.1	39	55		
	{ July 17	No. 1 Y. M.	57.1	12.8	1.3	.. do ..	4.3	30	46	Aug. 9	Do.
	{ Jan. 28	No. 2 Y. M.	57.4	12.8	1.1	.. do ..	2.2	38	52		
2-14	{ July 17	No. 1 Y. M.	56.7	14.8	.9	.. do ..	5.0	34	49	Aug. 7	(³)
	{ Jan. 28	No. 2 Y. M.	57.0	14.7	.7	Musty	2.5	52	16		
	{ July 17	Sample Y. M.	56.6	15.0	1.0	O.K.	5.3	33	47	Aug. 8	(⁴)
1-7	{ Jan. 28	No. 2 Y. M.	56.0	14.7	.4	Musty	2.0	49	21		

¹ Y. M. = Yellow milo.² Includes cracked grain.³ Grain was moldy and caked and had heated, would stand vertically in all parts of bin except 5 to 6 inches on top and 3 to 4 inches adjacent to walls. No spoilage at floor, walls, or floor-wall joint.⁴ Same condition as in bin 1-7, except area of uncaked grain extended in 18 to 24 inches from door.

TABLE 3.—*Effect of moisture content on temperature of grain sorghum in storage, 1946*

Date	Average temperature, all locations, by bin number and indicated initial moisture content							
	No. 2-16 (10.6 percent)	No. 3-15 (10.6 percent)	No. 4-13 (11 percent)	No. 3-14 (12.1 percent)	No. 2-12 (12.6 percent)	No. 2-14 (12.8 percent)	No. 1-7 (14.8 percent)	No. 1-16 (15 percent)
Jan. 6-7	°F. 74.0	°F. 41.4	°F. 70.1	°F. ...	°F. 72.4	°F. 74.2	°F. 80.1	°F. 100.0
Feb. 4-6	40.3	...	41.9	44.2	41.2	41.4	41.1	42.6
Mar. 7-8	45.9	47.6	46.0	48.2	47.4	43.7	42.2	48.6
Apr. 8-9	56.8	55.7	60.8	56.6	58.2	58.0	59.5	57.3
22	58.2	58.4	55.8	54.7	57.7	57.5	61.4	57.6
May 6	62.2	60.2	62.2	60.0	61.0	61.0	63.0	61.8
21	59.2	60.6	59.3	60.8	60.8	58.7	61.9	60.4
June 5	64.8	58.7	57.2	59.8	64.0	63.8	68.4	64.6
17	70.0	68.6	67.8	69.1	72.2	73.4	78.5	79.8
July 1-3 .....	...	72.9	...	70.5	...	...	81.0	81.9
5 .....	...	...	...	...	...	...	81.4	83.4
8 .....	...	...	...	...	...	...	84.0	86.2
10 .....	...	...	...	...	...	...	87.6	86.0
12 .....	...	...	...	...	...	...	88.0	89.2
15	78.8	78.9	80.0	76.1	78.6	77.6	95.3	91.4
22 .....	...	...	...	...	...	...	99.0	98.0
24 .....	...	...	...	...	...	...	101.8	...
26 .....	...	...	...	...	...	...	102.8	102.6
31	81.4	...	...	81.3	...	81.8	102.0	104.9

apparent slight increase in germination in the other lots may have been due to sampling or experimental error and did not appear to be correlated with differences in moisture content in the range from 10.6 to 12.8 percent.

Notes recorded at the time the bins were emptied (footnotes 3 and 4, table 2) show that there was marked deterioration in the two high-moisture bins (1-7 and 1-16), but no visible deterioration in any of the others. These two bins had been heating, but no heat damage was found in the final grade samples.

The average temperatures of grain in these bins, as determined by temperature traverses on different dates, are recorded in table 3. Temperatures remained within safe limits and were not affected by grain moisture content until the June 17 reading. After that date, temperatures in the two high-moisture bins (1-7 and 1-16) increased steadily and were more than 20° F. above the temperatures in other bins on July 31.

The effect of moisture content on insect infestation, which was an important part of this experiment, is covered elsewhere in this report.

It is possible that a longer period of storage would have developed differences in storage results that did not show up in 6 to 8 months. These experiments, however, indicate that the safe limit of moisture content of grain sorghum for long-time storage in tight bins in Kansas is about 13 percent. Grain with moisture content up to 15 percent placed in storage in November is reasonably safe from heat or mold damage until the weather warms up in spring, but the effect on germination of this high moisture content in winter was not determined. It is probable that a somewhat higher limit of moisture content would be permissible in States north of Kansas and that a lower limit would be necessary farther south.

TURNING AND CLEANING

Turning grain (moving it from one bin to another) to prevent heating and deterioration is a common practice in terminal and country elevators. Moving wheat in storage in farm-type bins was tested extensively by Kelly et al.,⁵ who reached the following conclusions:

Moving and turning wheat by means of portable farm elevators or by shoveling is of little value in reducing the average wheat moisture content, although much benefit may be derived from the mixing of damp wheat with dry wheat placed in the same bin if the operation is undertaken before heating occurs. Similarly, little cooling of hot wheat is effected by turning unless the air temperature is well below the wheat temperature, although here again mixing of hot and cool portions will lower the maximum wheat temperature.

In the grain sorghum studies, four lots of grain that had started to go out of condition were turned—bins 7 and 46 (table 7, Appendix) and bins 43 and 47 (table 10, Appendix). Grain in bins 7 and 46 (tables 7, 10, Appendix) was cleaned in the same operation with turning. Molding was in localized pockets in each of these lots. The cleaning, removal of spoiled grain, and mixing of the remaining good grain was effective in arresting spoilage. All these lots were sample grade, owing to musty odor at time of turning. Grain in bins 7 and 46 (table 7, Appendix) still had musty odor 4 and 6 months later, but there was no severe spoilage after turning. Grain in ventilated bin 7 was held for an additional year of storage, and at the end of that time the musty odor had disappeared and the grain was graded No. 1. In ventilated bins 43 and 47 (table 10, Appendix) the musty odor had disappeared 3½ months after turning and the grain was graded

⁵ See footnote 4, p. 10; Circular 637, p. 141.

No. 2. These results are in accordance with conclusions quoted on wheat-storage studies.

When bins 7 and 46 (table 7, Appendix) were emptied and cleaned it was observed that molding and caking was severe in locations where an excess of dockage, foreign material, and cracked grain had accumulated



FIGURE 9.—Spoiled sorghum grain caused by accumulation of cracked grain and foreign material. (See also figure 14.) (Magnified about $\times 6$)

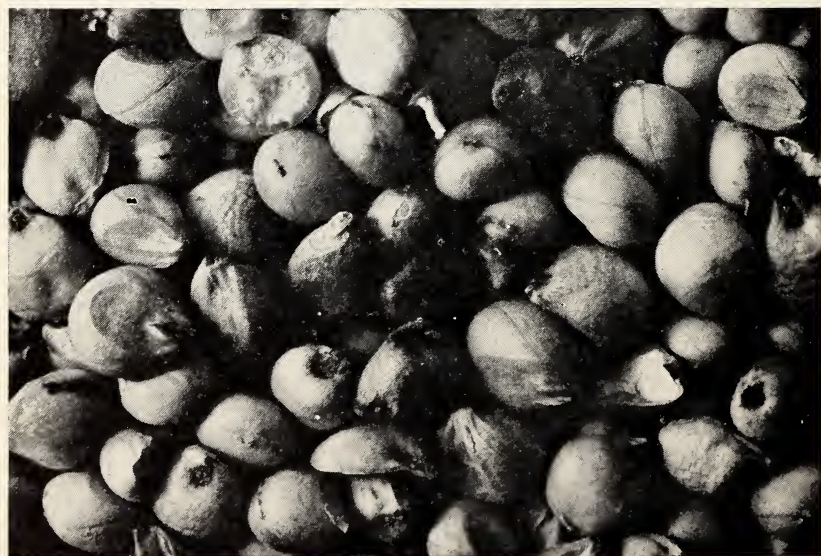


FIGURE 10.—Sorghum grain in good condition where free from cracked grain and foreign material. (Magnified about $\times 6$)

when the bins were first filled, whereas the grain was in good condition in locations where it was clean (see figs. 9 and 10). Clean threshing is especially important with grain sorghum because bits of sorghum or weed stalks are likely to have a high moisture content. If the grain is clean when placed in storage no benefits should be expected from additional clearing during the storage period.

REMOVING EXCESS MOISTURE

If grain sorghum contains more than about 13 percent moisture when combined or threshed, it should be dried to prevent damage in storage. Farmers have used different methods of handling damp grain. If there are only a few loads with slight excess of moisture, mixing with drier grain may be effective, but not unless mixing is thorough. Spreading the grain in a thin layer on a clean floor with good air circulation above it is an effective method if the grain is not excessively wet. In dry areas damp grain is frequently dumped in small piles or ricks outdoors, where it is exposed to sun and wind until dry. This method, of course, is subject to a weather hazard. All these methods require extra labor in handling, and on many farms there may be no sheltered floor space available for spreading grain in a thin layer.

None of these methods was tested experimentally. An attempt was made to develop structures and methods that would dry damp grain more reliably and economically. Several designs of ventilated bins were tested in which air was moved through the mass of grain by wind action. Tests were made of power ventilation of the grain with both unheated and heated air.

WIND-ASSISTED VENTILATION

The different types of wind-assisted ventilation that were tried experimentally in round steel bins are shown diagrammatically in figure 11. The storage results with these bins were as follows.

Type A.—Perforated walls, perforated central tube to suction cowl. Bin No. 43 at Hays, a 500-bushel bin with air path through the grain $4\frac{1}{2}$ feet, was filled in April 1939 with grain sorghum containing 13.9 percent moisture (tables 4 and 5, Appendix). When the bin was emptied on October 31, 1939, the moisture content was down to 9.6 percent and the grain graded No. 1, although there were small musty pockets near the floor. Good weather conditions for drying prevailed during this test.

Type B.—Perforated walls, perforated central tube to pressure cowl. A pressure cowl was installed instead of the suction cowl on bin No. 43 in November 1939, changing the bin type from *A* to *B*. The bin was filled in November 1939 with grain sorghum containing 17.3 percent moisture (tables 6, 7, and 8, Appendix). Temperatures of grain in this bin followed atmospheric temperatures more closely than in other bins under test at the same time. There was no heating of the grain. When the bin was emptied in October 1940 the average grain moisture content was down to 11.2 percent and the grain graded No. 3. About 1 inch depth of musty grain was found on the floor near the north wall. Probably this was caused by rain blowing through wall perforations and running down to the floor on July 1, 1940.

Type C.—Perforated walls, perforated central tube not connected with any cowl. In November 1940 the suction cowl on Hays bin No. 43 was replaced with a roof cap. The central perforated tube was opened to

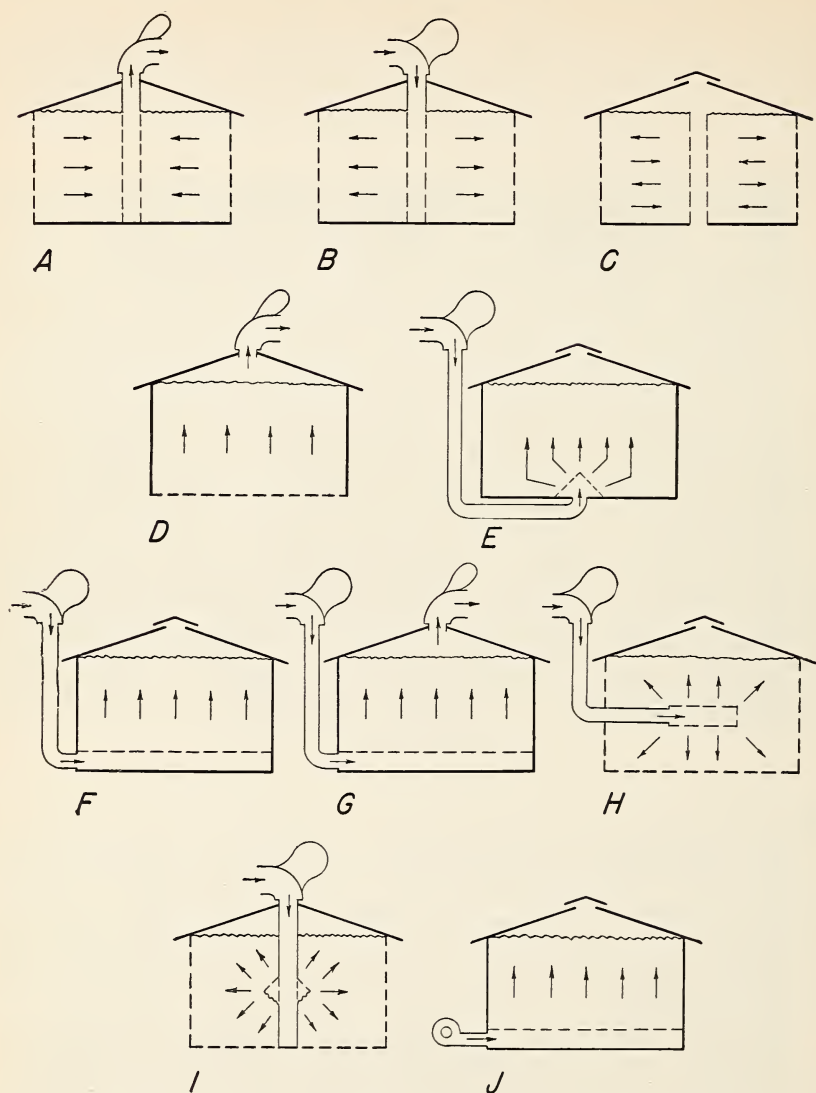


FIGURE 11.—Types of ventilated cylindrical steel bins—arrows indicate direction of air flow: *A*, Perforated walls, perforated central tube to suction cowl; *B*, perforated walls, perforated central tube to pressure cowl; *C*, perforated walls, perforated central tube not connected with any cowl; *D*, perforated floor, suction cowl in sealed roof; *E*, perforated conical air chamber on floor connected with pressure cowl; *F*, air chamber under perforated floor connected with pressure cowl; *G*, air chamber under perforated floor connected with pressure cowl, suction cowl in sealed roof; *H*, perforated floor and walls, central perforated air chamber connected with pressure tube; *I*, perforated floor and walls, central perforated air chamber connected with pressure cowl; *J*, air chamber under perforated floor connected with power blower.

atmosphere at the bottom and to air space under the roof but not connected with any cowl, making the bin type *C*. On November 5, 1940, this bin was filled with grain sorghum containing 15.1 percent moisture (tables 9 and 10, Appendix). Grain was heating and had musty odor the following July. (See comments on table 10, Appendix, for details.) Ventilation was not successful in this test, partly because of rain blown through wall perforations.

Type D.—Perforated floor, suction cowl in sealed roof. Hays bin No. 11 was a wooden bin of 100-bushel capacity. On November 18, 1939, it was filled to 5.8 feet depth with 90 bushels of grain sorghum containing 19.9 percent moisture (tables 6 and 7, Appendix). The grain heated and had to be removed from the bin the eighth day of storage. Hays bin No. 46, a 1,000-bushel type-*D* bin, was filled on November 9, 1939, to 8 feet depth with grain sorghum containing 17.3 percent moisture (tables 6, 7, and 8). The grain began to heat soon after filling. It was ventilated with a power blower in November and again the next April. (See footnote 5, table 7, Appendix, for details.) Wind-assisted ventilation was not successful in this case. Hutchinson bin No. 1/2-16, a 1,000-bushel type-*D* bin, was filled to 8 feet depth on April 8, 1942, with grain sorghum containing 12.5 percent moisture (table 12, Appendix). Owing to humid conditions during the summer the average moisture content increased to 13.3 percent in August. It was down to 12.6 percent the following February. Grain in this test was dry enough to have stored satisfactorily in a tight bin.

Type E.—Perforated conical air chamber on floor, connected with pressure cowl. Hays bin No. 2, a 500-bushel type-*E* bin, was filled to 7 feet depth on November 23, 1939, with grain sorghum containing 17.0 percent moisture (tables 6, 7, and 8, Appendix). Its moisture content was reduced gradually to 12.1 percent by August 7, 1940, when it was graded No. 2. Wind-assisted ventilation was successful in this test, but weather conditions were more favorable than usual.

Type F.—Equipped with an air chamber under perforated floor connected with pressure cowl. Hutchinson bin No. 1/2-4, a 1,000-bushel type-*F* bin, was filled on April 17, 1942, to 8 feet depth with grain sorghum containing 13.6 percent moisture (table 12, Appendix). Humid weather conditions increased the moisture content during the summer, but the grain dried to 12.8 percent during the fall and winter without change in commercial grade. The initial moisture content was not high enough to make a good test of ventilation. The gain in moisture during the summer indicates that no system of ventilation with unheated air would have dried the grain under weather conditions then existing.

Type G.—In the fall of 1940, the 1,000-bushel Hays bin No. 46, with an air chamber under perforated floor connected with pressure cowl, suction cowl in sealed roof, was remodeled to type-*G* and on November 9, 1940, was filled to 7.5 feet depth with grain sorghum containing 15.3 percent moisture, sample grade, sour (tables 9 and 10, Appendix). Under humid weather conditions in the following winter and spring, the grain lost no moisture and until late in the summer had a musty odor but dried to 12.3 percent moisture and graded No. 2 in October 1941.

Type H.—Hays bin No. 7, a 1,000-bushel type-*H* bin, had perforated floor and walls and a perforated central air chamber 4 by 4 by 2 feet connected with pressure cowl, making the length of air path through the

grain 3 to 5 feet when the bin was filled to a depth of 8 feet. The bin was first filled in March 1939 with grain sorghum containing 13.9 percent moisture (tables 4 and 5, Appendix). The moisture content was reduced to 9.5 percent by October 1939 without change in commercial grade. In November 1939 the grain was removed from this bin, cleaned, wetted to 17.3 percent moisture, and replaced (tables 6, 7, and 8, Appendix). Before the refilling, the entire wall was lined with paper to prevent air movement through the wall perforations. The grain did not dry fast enough in the spring of 1940 and became musty. In April 1940 the grain and the paper lining were removed from the bin, and the grain cleaned and replaced, after which it dried satisfactorily. This grain was held in bin No. 7 until January 1942 (tables 9 and 10, Appendix). There was no further evidence of damage after April 1940, except for a small amount due to rain leakage through wall perforations, and the musty odor disappeared, so that the grain graded No. 1 at the end of the experiment.

Type I.—Hays bin No. 47 was a 1,000-bushel type-*I* bin, with perforated floor and walls, and central perforated air chamber connected with pressure cowl. The ventilating action and dimensions were similar to those of type-*H* bin No. 7; it was filled in November 1940 with the new crop grain sorghum containing 15.5 percent moisture (tables 9 and 10, Appendix). About 20

bushels of grain next to the north wall was damaged by water, which entered wall perforations in a rain accompanied by high wind on April 6, 1941. Dark fluid seeping out through wall perforations from spoiled grain is shown in figure 12. The grain did not dry as fast as necessary to prevent mold growth during the spring of 1941. This probably was a result of unusually humid weather. The performance of the bin was satisfactory during the last 9 months of 1941. (See comments on table 9, Appendix, for details.) Hutchinson bins Nos. 2-17 and 3-16, each 1,000-bushel type-*I* bins of the same design as Hays bin No. 47, were filled in April 1942 with grain sorghum containing about 13 percent moisture (table 12, Appendix). The grain was stored for 10 months without visible

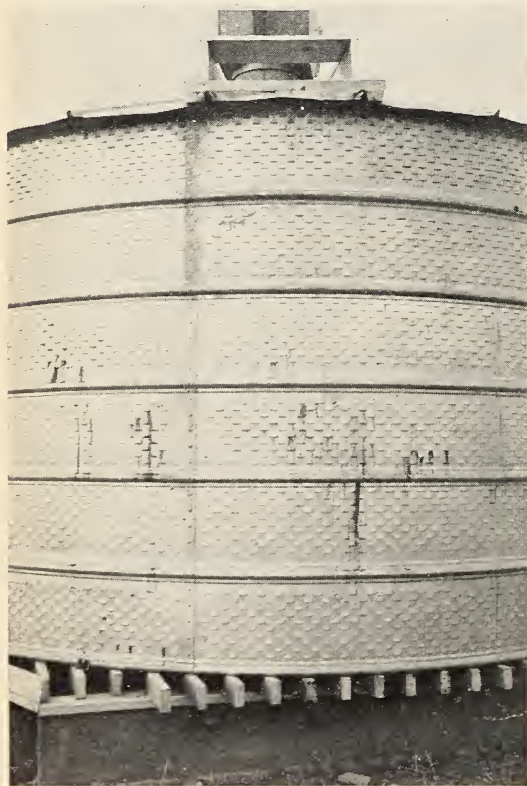


FIGURE 12.—Bin 47, showing dark fluid seeping through perforated wall from spoiled grain. April 11, 1941.

deterioration, but the initial moisture content was low enough for storage in a tight bin.

The results obtained by wind-assisted ventilation of damp grain in bins described in figure 11 indicated that 7 to 8 feet was too long an air path through the grain except under favorable conditions. The best results in drying the grain were obtained in types *H* and *I* bins in which the length of the air path through the grain was 3 to 5 feet. Under humid weather conditions in the spring of 1941 grain did not dry satisfactorily in types *H* and *I* bins. Other objections to these two types were: (1) Rain accompanied by high wind entered wall perforations; (2) the grain was not properly aerated unless the bin was filled to full depth; and (3) the bin was not adapted to effective fumigation to control insects.

Under normal weather conditions grain in bins with wind-assisted ventilation was conditioned and preserved with an initial moisture content from 2 to 4 percent higher than would be safe in a tight bin; hence it was thought desirable to attempt further improvement. Consequently, two



FIGURE 13.—Specially designed wooden bin for drying grain sorghum, equipped with a large pressure-type cowl, an outlet vent in the gable end, and a sheet-metal covering for the south wall and roof.

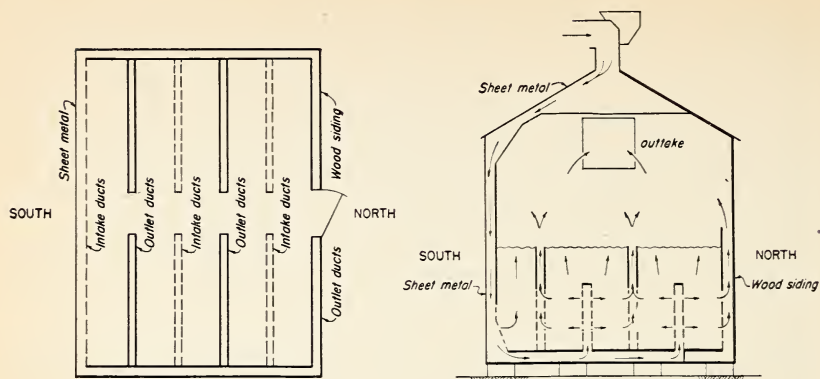


FIGURE 14.—Plan and cross section of wooden bin shown in figure 13.

wooden bins at Hutchinson were remodeled, as shown in figures 13 and 14. A large pressure cowl was used above the roof. The south slope of the roof and the south wall, which were exposed to the sun, were covered with sheet metal painted black. Air from the cowl was conveyed downward in contact with these metal surfaces, under the floor, and to vertical perforated ventilators placed above the floor in the grain. It then passed through 2 feet of grain to a second set of perforated ventilators, which carried the air upward to the space above the grain and thence to outside air. The sheet metal south wall and roof did not prove to be effective in heating the air, however, and probably had little to do with the performance of the bin.

In the fall of 1944 these two bins were filled with grain sorghum containing 14.5 percent moisture. The moisture changes in these bins are shown in figure 15. Temperatures are recorded in table 14, Appendix. The cowl was connected continuously with bin No. 1 but was removed from bin No. 2 from November 27, 1944, to August 11, 1945. Grain in bin No. 1 dried satisfactorily in the spring of 1945 even though the weather was unusually humid. The grain was stored for 17 months, during which time it dried below 12 percent moisture and did not deteriorate in any grade factor.

Although the grain in this bin was protected from rain by tight walls and the bin could be fumigated effectively, it still had two objections: (1) The perforated interior ventilators were an inconvenience when emptying the bin; and (2) the grain was not uniformly ventilated unless there was a fixed quantity in the bin.

Reference is made to tests by Kelly et al.,⁶ that showed that the pressure cowl was considerably more effective than the suction cowl in forcing air flow through grain. They found that in North Dakota an objectionable quantity of snow entered the pressure cowl in high winds, but in the investigations in Kansas no snow damage to the grain was observed.

BIN FOR STORING DAMP GRAIN

As a result of these studies of wind-assisted ventilation, a bin such as that illustrated in figure 11, *F*, with depth of grain determined according to moisture content, is suggested as the most practical type for storing damp

⁶ KELLY, C. F., CROSEY, M. G., and SWANSON, W. R. PERFORMANCE OF COWLS FOR VENTILATED GRAIN BINS. *Agri. Engin.* 23 (5): 149-151. 1942.

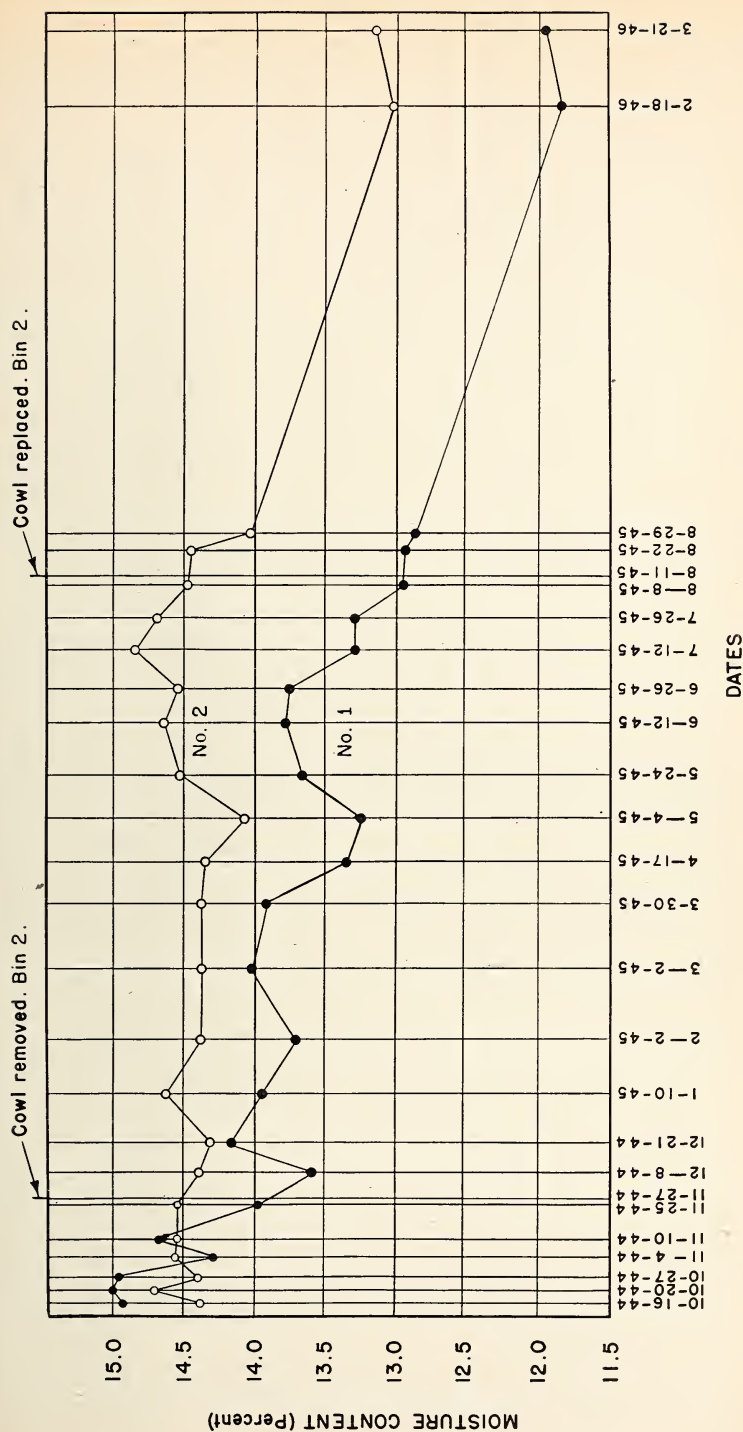


FIGURE 15.—Change in average moisture content of yellow milo in bins equipped with pressure cowls. Bin No. 1, in which cowl was operated continuously; bin No. 2, in which cowl was operated intermittently.

grain on farms in dry climates. The pressure cowl could be placed above the peak of the roof, if preferred, and connected by a tight vertical pipe with the air chamber under the perforated floor. The floor and lower walls must be airtight, so that all air will be forced through the grain.

Usually it would be best to place not more than 4 feet depth of damp grain in the bin. The depth should be varied with the moisture content of the grain and the quantity to be dried. That is, for grain of 15 percent moisture content, the bin might be filled 6 feet deep, while for grain of 18 percent moisture content, the depth should not be more than 3 feet.

This bin is simple in construction, can be filled and emptied with reasonable convenience, is adaptable to variable quantities of grain, is well protected from the weather, and is adapted to fumigation for insect control. If properly managed, this type of bin can be expected to condition and preserve grain having initial moisture content up to 18 or 20 percent in a relatively dry climate, such as that at Hays, Kans.

The best perforated floor found for this type of bin was perforated galvanized sheet steel. The perforations should be slots narrow enough to prevent passage of grain. The area of the perforations should be at least 6 percent of the floor area. A floor of fly screen over hardware cloth has been used in some cases, but such material is likely to be damaged when the bin is emptied.

The sizes of cowls and air pipes suggested are as follows: For a bin 14 feet in diameter, air pipe not smaller than 12 inches diameter with cowl to fit; and for a bin 10 feet in diameter, air pipe not smaller than 10 inches diameter with cowl to fit.

POWER VENTILATION WITH UNHEATED AIR

A study was made of conditioning damp grain by power ventilation with unheated air in bins similar to those illustrated in figure 11, *J*. Some bins were changed only temporarily to this type for the purpose of cooling heated grain.

Hays 500-bushel bin No. 1 was filled in November 1939 with grain sorghum containing 15.2 percent moisture (tables 6, 7, and 8, Appendix). The grain began to heat about July 1, 1940. It was ventilated with a power blower for about 400 hours from July 8 to 25, with air movement through the grain estimated at 10 cubic feet per minute per square foot of floor. The condition of the grain was changed from 14.6 percent moisture, musty odor, on July 8 to 12.5 percent moisture, natural odor, on August 7.

Hays 1,000-bushel bin No. 46 was filled on November 9, 1939, with grain sorghum containing 17.3 percent moisture (tables 6, 7, and 8, Appendix). The grain began to heat in about a week. On November 25 its average temperature was 66.6° F. and at one point it was 107°. Ventilation with power blower for 48 hours from November 25 to 27 reduced the average grain temperature to 42°, with the hottest point 43°. The grain was going out of condition in April 1940. It was therefore removed, cleaned, and replaced in the bin and then ventilated with a power blower for 276 hours between April 15 and May 10. The average grain moisture content was reduced from 16.8 percent on April 10 to 13.3 percent on June 1, but the musty odor was not removed.

Hays 500-bushel bin No. 1 was filled on November 7, 1940, with grain sorghum containing 15.8 percent moisture (tables 9 and 10, Appendix). Because it heated and had a musty odor, the grain was given power

ventilation for 408 hours from June 5 to 23, 1941. Within a few hours after the blower was started, the average temperature of the grain was reduced from 94.8° to 71.5° F. Because of humid weather, the grain moisture content was not reduced by power ventilation. The average grain moisture content on June 28 was 16.3 percent, which was 0.5 percent higher than when the bin was filled.

Hutchinson type-*J* bins Nos. 3-2, 4-1, 4-2, and 4-3, all 1,000-bushel bins, were connected with a power blower by pipes to a plenum chamber with gates for dividing the air flow to each of the four. In December 1941 bins Nos. 3-2, 4-1, and 4-2 were filled to 8 feet depth with grain sorghum containing, respectively, 15.2, 14.8, and 20 percent moisture. The grain was hot when placed in bin No. 4-2. After 4 days of power ventilation, with an estimated air flow of 7 cubic feet per minute per square foot of floor, the average grain temperature in this bin was reduced to 21° F., and there was no more trouble from heating. Because of humid weather conditions in the spring these bins were not power ventilated until May 13, 1942. Changes in grain moisture, temperature, and commercial grade are recorded in table 11, Appendix, and the blower schedule is shown in table 13, Appendix. (See comments on table 11, Appendix, for full details.)

In bin No. 3-2 the average grain moisture content was reduced from 15.1 to 12.6 by 1,169.5 hours of power ventilation from May to July 1942. No heating of the grain occurred, but mold growth and musty odor developed during May and June. The musty odor had disappeared at the time of final sampling in September. The long period of ventilation in this test was required because of humid weather and excessive rainfall.

In September 1944 bins Nos. 4-1, 4-2, and 4-3 were filled to 4 feet depth with grain sorghum containing, respectively, 15.8, 15.8, and 15.4 percent moisture. The grain was sour and heating when placed in the bins. Grain temperatures were reduced to approximately atmospheric temperature by 4 hours of power ventilation with air flow of about 11 cubic feet per minute per square foot of floor. Under favorable conditions for drying, 147 hours of power ventilation reduced the average grain moisture content (in bin No. 4-1, for example) from 15.8 to 12.3. Changes in moisture content and temperature of the grain are recorded in table 15, Appendix, and the blower schedule is shown in table 16. The results obtained in this test are in marked contrast with those obtained from May to July 1942, when 1,169.5 hours of power ventilation were required to effect a smaller reduction in grain moisture content. The difference in results is accounted for by a difference in weather conditions and by the fact that the bins were filled to 8 feet depth in 1942, but to only 4 feet depth in 1944. With the blower developing the same pressure in both cases, the quantity of air flowing through 4 feet depth of grain would be about 50 percent greater than through 8 feet depth; the quantity of air per bushel of grain would be about three times as much with 4 feet depth.

These tests of power ventilation of damp grain with unheated air showed that—

1. The temperature of heating grain is reduced promptly by power ventilation with an air flow of 7 cubic feet per minute per square foot of floor through 8 feet depth of grain.

2. Drying of the grain depends on the temperature and humidity of the air. Grain was dried slowly or not at all at winter temperatures. In

periods of high relative humidity (more than 70 percent) at summer temperatures, drying was too slow to prevent mold growth in 8 feet depth of grain. Drying is much more rapid in 4 feet than in 8 feet depth of grain. Therefore, 4 feet is suggested as a more practical depth.

Under favorable weather conditions power ventilation with unheated air is an economical method of conditioning damp grain containing up to 20 percent moisture, but this method is not entirely successful when the relative humidity is 70 percent or higher.

DRYING WITH HEATED AIR

A series of preliminary laboratory tests was made to determine the relation between initial grain moisture content, air temperature, air humidity, rate of air flow through the grain, quantity of grain, and rate of drying at each location within the bulk of the grain. These investigations are discussed in a paper, "Basic principles in drying corn and grain sorghum," by W. V. Hukill.⁷ Results indicate that drying is more rapid with heated than with unheated air and can be carried on in all kinds of weather. Therefore, drying with heated air is more reliable, and with a good design of drier it may prove to be as economical as drying with unheated air or even more so. Further information on drying grain sorghum with heated air is in preparation.

ENSILING SORGHUM GRAIN

A small-scale test of the effect of a moisture content of from 17 to 38 percent on quality of sorghum grain silage was made at Hutchinson from October 1944 to April 1945. The grain used was the 1944 crop that had been heating and molding at 14.4-percent moisture in September, but had been dried artificially to 12.5-percent moisture and held for 6 weeks before the ensiling test was begun. The different lots of silage were wetted to the desired moisture content at the time of ensiling early in November.

The silage was stored in 10 wooden barrels, each containing 6 bushels. The test included 2 barrels at 19-percent moisture, 2 at 20 percent, 2 at 21 percent, and 1 each at 24, 30, and 38 percent, also 1 barrel of cracked grain at 17-percent moisture. The barrels were placed upright in a trench a little shallower than their height and were filled heaping full of silage, then covered with kraft paper and roll roofing. The trench around the barrels was then filled with soil, and this was heaped up to about a foot depth over the roll-roofing cover.

The barrels were uncovered for examination and sampling of the silage on April 6, 1945. The silage was found to be moldy in the upper part of the barrel in all lots, but all contained some good silage in the bottom of the barrel. The lots containing 24-, 30-, and 38-percent moisture had good silage to depths of 2 inches, 12 inches, and 18 inches, respectively, at the wall and rising to a high crown in the central part of the barrel. In the drier lots the moldy condition extended downward along the wall to the bottom of the barrel, but there was good silage in the central part of the barrel somewhat below midheight.

The results of this small-scale test are not conclusive with respect to the practicability of preserving damp sorghum grain by ensiling. The amount of top spoilage was possibly more than could be tolerated in farm practice, but this was due partly to the use of small lots without an effective air

⁷ HUKILL, W. V., BASIC PRINCIPLES IN DRYING CORN AND GRAIN SORGHUM. Agr. Engin. 28 (8). 335-340. 1947.

seal at the top of the barrel and to the previous moldy condition of the grain.

Samples for feeding-stuff analyses were taken from the good silage in the 17-, 19-, 21-, 30-, and 38-percent moisture lots. The results are recorded in table 17, Appendix. Moisture content had little effect upon the protein, fat, or carbohydrates in the silage, but the high moisture content resulted in higher acidity. Estimates of palatability favored the lots containing 19- to 24-percent moisture.

INSECT INFESTATION IN FARM-TYPE BINS

Observations were made at Hutchinson on the degree and kind of insect infestation that developed on that site, on approximately 19,000 bushels of grain sorghum stored in 1,000-bushel circular galvanized steel bins. The moisture content of the grain varied from 10.5 to 15.5 percent. By means of periodic sampling in various parts of the bins, the kind and intensity of insect populations in grain sorghum of various moisture contents was determined throughout the period of storage.

During the winter of 1941-42 an 8,000-bushel lot of grain sorghum varying in moisture content from 12.5 to 13.6 percent was brought in boxcars to the Hutchinson Experimental Grain Storage Project for experimental purposes (tables 11 and 12, Appendix). At the time of arrival insect infestation was negligible. It was stored throughout the summer of 1942 and the following winter and shipped out in March 1943. Although the initial infestation was low, by August 1942 all the bins had begun to heat as a result of insect infestation and all the grain graded "weevily." The increase in infestation during storage in 1942, based on number of insects per 1,000 grams, is shown below:

	<i>Weevils</i>	<i>Bran beetles</i>
April	0	0.4
August	1.6	13.5
September	1.8	15.2
October	4.5	27.8

During August the bins were fumigated with dosages that had been found effective for the fumigation of wheat but proved to be inadequate for grain sorghum. For this reason but little reduction in the insect population was effected by the fumigation, although the heating was arrested temporarily. Late in the season fumigation with increased dosages brought the infestation under control.

In September 1944 approximately 3,300 bushels of high-moisture grain sorghum was obtained for experimental work in wind-ventilated and mechanically ventilated bins (tables 14 and 15, Appendix, figs. 14 and 15). This grain was heating and was sour when unloaded from the cars, and on arrival at the storage site grain temperatures of 130° F. were observed. By means of various types of ventilation the moisture content was reduced from about 15.5 to 13 percent, and the grain carried in storage through the succeeding year without deterioration, grading No. 2 Yellow Milo when shipped out. During the summer of 1945 dangerous insect populations developed in all the bins and they were fumigated. Ventilation features used in the construction of the bins made fumigation difficult, but with heavy dosages of fumigant the insect infestation was brought under control.

During the winter of 1945-46, eight 1,000-bushel steel bins were filled with grain sorghum of different moisture contents for the purpose of studying the effect of moisture on keeping qualities and also on the extent of

insect infestation. This series consisted of two bins each of grain sorghum with moisture contents of 10.5, 12.0, 12.5, and 15.0 percent. On arrival at the storage site there was no observable insect infestation. During the storage period, from January to July 1946, samples were drawn periodically from different parts of the grain mass and the kind and degree of insect infestation was noted. The rate of increase in the insect population in the grain sorghum of different moisture contents is shown in table 18, Appendix. It will be noted from the table that insect infestation was first found on May 4, that by the second week of July it had increased to dangerous levels, and that the infestation in the bins containing the 15-percent-moisture grain sorghum was less intense than in grain of lower moisture content. This condition was possibly due to the presence of fermentation gases, inasmuch as the high-moisture-content grain began heating early in June.

To obtain information as to the location of the insect infestation within the bins, samples were taken with a grain probe from the center, north, east, south, southwest, west, and surface parts of the grain. These samples were then examined and the number and kind of insects noted and infestation computed, on the basis of number of insects per 1,000 grams of grain. The infestation in the several sampling locations in the bins is given in table 19 as percentages of the total number of insects found. It will be noted in the table that the insects were most numerous in surface locations. This may be accounted for by the fact that migrating insects enter the bin through ventilator openings and small openings in the junction of the roof and wall. Previous experience with wheat stored under the same conditions shows that later in the season the insects tended to concentrate in the south portion of the grain mass. Since this study had to be terminated late in July of 1946, it was not possible to determine whether changes in the distribution of insect populations in grain sorghum would follow the same yearly trends as in wheat stored under the same conditions.

Altogether six species of stored-grain insects were found in the grain sorghum. These, together with their comparative abundance, are listed in table 20, Appendix. The lesser grain borer and the saw-toothed grain beetle were the dominant species in grain sorghum of 12.5 percent moisture or less, and the flat grain beetle in bins containing sorghum of 15 percent moisture. In wheat stored on the same site, the dominant species were the lesser grain borer and the flat grain beetle.

CONTROL OF INSECTS INFESTING GRAIN SORGHUM

In 1946 the sorghum was fumigated with a mixture of 3 parts of ethylene dichloride and 1 part of carbon tetrachloride applied at the rate of 8 gallons per 1,000 bushels. This gave perfect kills in all bins except the two containing 15-percent-moisture grain sorghum. In these, the kill was 92 percent. This is in line with past experience in fumigating high-moisture corn and wheat. The dosage of 8 gallons per 1,000 bushels is twice what is required for wheat stored under similar conditions. From the results obtained in this work, it would appear that for the successful fumigation of grain sorghum stored in steel bins, much higher dosages are required than for wheat stored under the same conditions. In general, a dosage of twice that required for wheat is recommended for grain sorghum. Five

fumigants and dosages for grain sorghum stored in steel bins are recommended as follows:

Fumigant:	Dosage per 1,000 bushels (gallons)
Ethylene dichloride, 75 percent; carbon tetrachloride, 25 percent.....	8
Ethylene dichloride, 35 percent; carbon tetrachloride, 60 percent; ethylene dibromide, 5 percent	6
Carbon tetrachloride	6
Carbon tetrachloride, 80 percent; carbon bisulfide, 20 percent.....	6
Carbon tetrachloride, 95 percent; ethylene dibromide, 5 percent.....	6

In grain sorghum stored in wooden farm granaries the above dosages should be increased 25 percent.

If grain sorghum is to be stored in farm-type bins during the summer following harvest, or for a longer period, a severe insect infestation is likely to develop. For this reason frequent inspection of the grain should be made beginning in July and, if one or more weevils or 15 or more bran beetles per quart of grain are found, it should be fumigated. For long-time storage (more than 1 year) the practice of regular fumigation in late August or early September should be followed.

The presence of large numbers of insects in stored grain will cause it to heat, even though the moisture content is below the safe level for long-time storage. A simple method of determining whether the grain is heating is to thrust an iron rod, pipe, or fork handle into the grain in the southwest part of the bin, and then, if the rod or handle is hot when pulled out, the grain should be fumigated, provided examination shows the presence of a dangerous insect infestation as specified above.

In applying the fumigant to a bin of grain, the fumigator should avoid inhaling any of the vapors, even those from light concentrations, and should also avoid spilling this or any mixture containing carbon tetrachloride on the clothing or hands.

The most satisfactory method is to apply the fumigant from the outside of the bin. An inexpensive bucket sprayer or a larger power-sprayer is used to spray the liquid uniformly over the surface of the grain. It is unwise to attempt to apply the fumigant with a sprinkling can, since the vapors have an anaesthetic action when breathed in concentrated form, and fumigators exposed to the vapors for any appreciable period are likely to be made seriously ill. A gas mask provided with a full facepiece and a black canister approved by the United States Bureau of Mines for protection against these gases should always be worn by anyone who is exposed to the concentrated vapors for more than a very brief period.

APPENDIX

[Tables 4 to 20]

The following comments on tables 7, 9-12, and 15 in the Appendix explain details of the experimental storage of the different lots of grain in the grain sorghum storage studies reported in this circular.

TABLE 7

1. Temperatures of the grain in bin No. 1 were normal until about July 1, 1940, when heating started. At 7:40 a.m. on July 8 the average temperature of the grain was 94.6° F. and at the hottest point measured 100.8°. Ventilation with a power blower was started on July 8 and continued with only minor interruptions until July 25. Air was forced under the perforated floor and upward through the grain. Air pressure under the floor was 1.2 inches water column. Air movement through grain was estimated to be 10 feet per minute. Sampling on July 8 showed average moisture content 14.6 percent, odor musty; on August 7, moisture 12.5 percent, odor natural. Sampling on August 31 showed slightly sour odor in the central part of the bin.

2. When bin No. 7 was unloaded for cleaning on April 25, 1940, it was observed that molding and mustiness were pronounced in locations where cracked grain and foreign material accumulated when the bin was filled. About 30 bushels of grain at the east wall was severely caked and molded. Grain in the rest of the bin was not caked. About 30 bushels of fine material was removed in cleaning this grain. The clean grain was returned to the bin after removing the paper lining from the perforated walls. Moisture content of the grain dropped gradually after the paper lining was removed from the wall, from 15.5 percent moisture on April 25 to 9.4 percent on August 1, 1940. Grain in this bin graded Natural Odor when filled on November 10, 1939, but Musty on January 30, 1940, and at each sampling thereafter.

3. Grain in bin No. 11 started to heat soon after filling. On November 26, 1939, the average temperature of the grain was 95.5° F. and at the hottest point measured 138°, when the grain was taken out of the bin and placed in a truck. The suction cowl was replaced by a pressure cowl. The grain that had cooled and dried slightly was replaced in the bin. Again the grain began to heat and was then removed and spread out in a thin layer on the floor of a 2,000-bushel bin in the seed house. No further experimental use was made of this grain.

4. Temperatures of grain in bin No. 43 followed atmospheric temperature changes more closely than in any other bin. There was no heating of the grain. When the bin was unloaded on October 26, 1940, about 1 inch of musty grain was observed on the floor along the north wall. Probably this was caused by rain blowing through the wall perforations and accumulating on the tight floor on July 1.

5. Grain in bin No. 46 began to heat about a week after filling. Temperatures increased gradually until at 11:45 a.m. on November 25, 1939, the average temperature was 66.6° F. and at the hottest point measured 107°. The bin was ventilated with a power blower from 11:45 a.m., November 25, to 11:45 a.m., November 27. At 8:55 a.m. on November 27 the average temperature of grain in the bin was 42° and at the hottest point measured 43°.

Sampling on April 10, 1940, showed musty and sour odors in some parts

of the bin. Grain was removed and cleaned and the clean grain returned to the bin on April 11. About 30 bushels of fine material was removed in cleaning.

As the bin was unloaded on April 11, it was observed that molding and mustiness were pronounced in locations where cracked kernels and foreign material accumulated when the bin was filled. The grain was caked slightly throughout the bin, and a 10-bushel portion about 2 feet north of the loading door was severely molded and caked.

The bin was ventilated with a power blower 276 hours from April 15 to May 10, 1940.

The average sample taken from this bin at the beginning of the test on November 11, 1939, graded Natural Odor, but samples from middle and bottom of the bin graded Musty. Average samples taken on January 30, 1940, and at each sampling thereafter graded Musty.

TABLE 9

1. Grain placed in these bins (except No. 7, which was 1938 crop, bin not emptied at this time) was new 1940 crop threshed by combine and hauled directly from combine to bin site. The moisture content as received varied from 9.9 to 14.5 percent. The grain was conditioned by spraying on water as the grain passed over the conveyor, then mixing the grain one or more times before placing it in storage. During the tempering period the grain became slightly sour and started to heat. Cold temperatures beginning on November 9 stopped the heating. (See also table 10.)

TABLE 10

1. Because of heating and musty odor, grain in bin No. 1 was ventilated by power blower beginning June 5, 1941, and operated 408 hours, ending on June 23. Within a short time after the blower was started the average temperature of the grain dropped from 94.8° to 71.5° F. On June 13 the average grain temperature was 65.6°. Because of some damp weather during this period, there was little, if any, reduction of moisture content of the grain. On June 28, as recorded in table 10, the average moisture content was 16.3 percent, which was 0.5 percent higher than when the bin was filled in November 1940. Temperatures in this bin remained about normal during July. The grain was "in poor condition" when moved from this bin in October 1941.

2. Grain was in bin No. 7 continuously from the time when it was turned and cleaned in April 1940 until it was sold in January 1942. The moisture content increased from 11.7 percent to 12.6 percent during the winter of 1940-41. Some water was blown through wall perforations in the storm of April 6, 1941, but no observation of any damage to the grain was recorded at that time. A small amount of spoiled grain was observed at the northeast wall near the floor in October 1941. When the bin was emptied in January 1942 about one-half bushel of grain was found caked to the northwest wall just above an instrument shelf attached to the outside of the wall.

3. Some rain water was blown through perforations in the north wall of bin No. 43 in the storm of April 6, 1941. Detailed observations of damage to grain were not recorded at that time but probably the condition was similar to that in bin 47, as described in paragraph 5.

Grain was removed from bin 43 for inspection on July 3, 1941. The grain was heating and had a decidedly musty odor. It was caked a good

deal as in bin 47. In addition there was badly spoiled grain on the floor extending in from the wall to the line of holes in the floor. The unspoiled grain was replaced in the bin after this inspection.

Grain in this bin remained Sample Grade due to sour or musty odor until the final sampling in October 1941, when the moisture content was down to 11.6 percent and the odor graded Natural. The final average sample graded No. 2 Yellow Milo. However, it was observed at that time that grain was caked near the north wall. When the bin was emptied in January 1942 about 1 bushel of slightly caked grain was found on the central part of the floor.

4. Grain in the upper part of bin No. 46 began to heat the first week in July. It was ventilated for 2 days with a power blower forcing air upward through the grain. After 4 hours of blower operation the grain was cool. Two days of blower operation reduced the grain temperature below that in other bins.

Grain in this bin remained Sample Grade because of sour or musty odor until the final sampling in October 1941, when the moisture content was down to 12.3 percent and the odor was natural. The final average sample graded No. 2 Yellow Milo. The grain was "in fair condition" at the time of final sampling in October 1941. When this bin was emptied in January 1942 "the grain appeared to be in good condition throughout the bin."

5. Rain water blown through perforations in the north wall of bin No. 47 in the storm of April 6, 1941, caused some damage to the grain. Figure 12 shows dark fluid seeping through the wall perforations from spoiled grain on April 11, 1941.

At the end of June 1941 grain was removed from bin 47 for a detailed examination of spoiled grain adjacent to the perforated walls. Approximately 10 bushels of black and badly decayed grain were immediately next to the north wall. An additional 10 bushels were molded and caked to a distance of about 8 inches from the north wall. About 2 bushels at the southwest wall were molded. Grain in the rest of the bin was in good condition. Galvanizing was destroyed on the inside of wall sheets in contact with badly spoiled grain. The good grain was replaced in the bin after this inspection.

Grain in this bin remained Sample Grade because of sour or musty odor until final sampling in October 1941 when moisture content was down to 12.2 percent and odor graded Natural. The final average sample graded No. 2 Yellow Milo. The grain was "in good condition." When this bin was emptied in January 1942, "the grain appeared to be in good condition throughout the bin."

TABLE 11

1. Four 1,000-bushel power-ventilated bins at Hutchinson, Kans. (3-2, 4-1, 4-2, and 4-3) were each constructed with a perforated sheet-metal floor supported on 2 by 4 wood joists set on edge, spaced 6 inches on centers. Under these joists was a tight chamber with earth floor. Air was forced into this chamber and upward through the grain by a multivane blower driven by a 5-hp. electric motor. Air from the blower entered a plenum chamber where it was divided into four pipes, one leading to each bin. Each pipe had a gate for regulating air flow. In operation, these gates were adjusted to maintain a static pressure of 0.75-inch water column in the air chamber under each bin floor.

Three of these bins were filled with grain sorghum in December 1941 and the fourth in April 1942. Data on changes in moisture, temperature, and grade as the grain was dried are recorded in table 12. Check bin $\frac{1}{2}$ -14 is included for comparison.

The plan was to operate the blower as necessary during the winter to prevent heating of the grain; then in the spring to operate whenever the atmospheric temperature was above 60° F. and the relative humidity below 65 percent. Due to excessive rainfall and humid conditions, the blower was not operated for drying until May 13, 1942. The schedule of blower operation is recorded in table 16. Operation was according to plan until June 6. It was observed at that time that grain in bins 3-2 and 4-1 was becoming distinctly musty, so the blower was operated continuously from June 6 to July 10 and again from July 14 to July 22. At the end of that time all of the lots were dried down to safe moisture content for storage.

2. Bins 3-2 and 4-1 were filled to about 8 feet depth in December 1941 with grain sorghum that contained close to 15 percent moisture and was obtained from farmers in the vicinity of Hutchinson, Kans. The results were much the same in both bins, the grain there becoming musty in May and June. The last grade sample from bin 4-1 was taken on June 9. Of the two samples taken from the bin on that date, each of which was a bin average, one sample graded Musty and the other Natural Odor. This indicated that the odor was on the borderline and the grain not severely damaged. The grain in bin 3-2 graded Musty until July 29, but Natural Odor on August 18. Grade factors other than moisture and odor did not change materially. Fat acidity increased about 10 units to June 9. There was a decrease in germination.

3. On December 27, 1941, bin 4-2 was filled with grain sorghum from a farm bin which was heating. The moisture content of the grain was 20 percent and the temperature 120° F. before moving. By power ventilation the temperature of this grain was reduced to 16° F. in 4 days. The musty odor persisted after the moisture content had been reduced to a safe limit, but the farmer who owned the grain sold it at "near-market" price.

4. Bin 4-3 was the same as the others, but an electric heating cable was installed 6 inches above the floor to provide some supplementary heat for drying. This was a lead-sheathed cable 120 feet long, consumed 800 watts, and had a rated surface temperature of 140° F. This cable was arranged in a spiral about 10 feet outside diameter. The heating cable was energized whenever the blower was operating, as recorded in table 13, until June 6. This bin was disconnected from the blower on that date because the grain was dried down to a safe moisture content. The amount of heat added in this experiment was too small to materially affect the rate of drying.

This bin was filled to a depth of about 8 feet on April 17, 1942, with grain sorghum containing 13.6 percent moisture taken from a railroad car. This grain was not moist enough for a good drying test. There was no material change in grade factors. Fat acidity increased about the same as in the check bin to June 9.

The results of power ventilation with unheated air in bins 3-2, 4-1, and 4-2 showed that heating of grain was arrested promptly by ventilation. Under humid weather conditions, power ventilation was not entirely effective in preventing deterioration of the grain. The blower was operated 1,169.5 hours to remove 2.6 percent moisture from the grain (bin 3-2).

TABLE 12

1. Bin No. $\frac{1}{2}$ -14 was a plain cylindrical steel bin, 14 feet in diameter, 8 feet high, with no provision for ventilation and a capacity of 1,000 bushels. The grain in this bin showed no change in moisture content, except within the range of possible error in sampling, and no material change in grade factors. Fat acidity increased from 31 to 51 units; germination decreased from 63 to 29 percent.

2. Bins 2-17 and 3-16 were cylindrical, of steel, 14 feet in diameter, and 8 feet high, with a 1,000-bushel capacity. They were equipped with a wind pressure cowl connected to a central perforated air chamber, perforated wall, and perforated floor supported above the ground to provide free air circulation under the floor. Construction was similar to that of Hays bin 47, previously described and illustrated in figure 11, *H*. The moisture content of grain in the bottom of these bins remained about stationary to August 15, but the average lot moisture decreased 0.5 to 0.7 percent to August 15 and another 0.1 to 0.3 percent to the following February. There was no apparent deterioration of grain next to perforated walls, as had been observed in previous tests of this type of bin, and no material change in grade factors. The results as to fat acidity and germination were about the same in bins 2-17 and 3-16 as in the check bin $\frac{1}{2}$ -14. Temperatures of grain increased to above 70° F. earlier in the summer, but decreased to below 70° earlier in the fall in these ventilated bins than in the check bin.

3. Bin No. $\frac{1}{2}$ -16 was a cylindrical steel bin, 14 feet in diameter by 8 feet high, with perforated floor and a 12-inch suction cowl above the peak of the roof, as shown in figure 11, *C*. The floor was supported above the ground to provide free air circulation under the perforated floor. Action of the suction cowl was to draw air upward through the perforated floor and 8-foot depth of grain.

The grain moisture record for this bin appears to be somewhat erratic. There was a loss of 0.4 percent moisture to the middle of June. No other bin showed a loss during this period. Then there was a gain of 1.2 percent from June to August. The August record shows materially higher moisture near the floor than at the top of the bin, indicating that moisture was moving up into the bin. The final moisture content was practically the same as at the beginning. Dockage increased from 0.6 to 1.9 percent; however, an average sample taken about a month before the end of the test showed only 0.5 percent dockage, so it is probable that the difference in dockage between initial and final samples was due to sampling error. There was no material change in other grade factors. Fat acidity increased from 31 to 55 units and germination decreased from 63 to 6 percent. The germination was the worst of any of the bins in this study, but the decrease in viability was ascribed largely to the effect of an experimental fumigant. Summer temperatures of grain in this bin were a little higher than in any other bin except $\frac{1}{2}$ -15.

4. Bin No. $\frac{1}{2}$ -15, a cylindrical steel bin of 1,000 bushels' capacity, was narrower and taller than the others, being 12 feet in diameter and 10 feet high. The cap at the peak of the roof permitted air movement but did not act as a cowl ventilator. For ventilation, the bottom of a 4-inch perforated tube, set vertically in the center of the bin, was connected to outside air by a horizontal 3-inch pipe running out to the south side of the bin.

There was a reduction of 0.5 percent in moisture content of the grain, nearly all of this taking place between August 15 and September 18. The original grade was No. 3, the test weight being slightly under the 53-pound limit for grade 2. A small increase in test weight brought the grade up to No. 2 at the end of the experiment. There was no material change in other grade factors. Fat acidity increased about the same as in the check bin. Germination dropped from 55 to 15 percent, which was not as good as the record in the check bin.

5. Bin No. $\frac{1}{2}$ -4 was a cylindrical steel bin 14 feet in diameter and 8 feet high. It had a perforated floor over a tight chamber connected to a 12-inch pressure cowl. Air moved upward from the perforated floor through 8 feet of grain and escaped through the roof cap. This bin is shown in figure 11, *F*.

Moisture content of grain in this bin increased slightly during the summer. The grain near the floor contained more moisture than that in the upper part of the bin at both June and August inspections. Moisture content decreased 1.0 percent from August 15 to the following February 8. Other grade factors did not change materially. Fat acidity increased about the same as in the check bin and germination decreased a little more than in the check bin.

TABLE 15

1. Bins 4-3, 4-2, and 4-1 were filled on September 15 and 16 in the order named with Yellow Milo from a car shipped from Hale Center, Tex. Each bin was filled to a depth of 4 feet. The grain was described as follows: Sample Grade Yellow Milo, test weight, 57 pounds; moisture, 15.7 percent; foreign material, 4.7 percent; sour and heating when car arrived. Temperature of 120° F. was observed in grain in the car before unloading.

Air from the blower was applied to each bin as soon as the floor was covered with grain and continued, as recorded in table 16. Bin 4-3 was blown for about 2 hours on September 15 (not shown in the table).

Changes in grain moisture and temperature are recorded in table 15. This table gives only typical moisture conditions after ventilation was ended. Moisture traverses were taken about once a month during storage. In every case during ventilation and generally until the following July the maximum moisture content in the grain was near the top of the mass of grain and the minimum near the floor. At the end of the period of power ventilation the bottom foot of grain contained 4.8 percent less moisture than the top foot. After July 1945 the maximum moisture content was usually in the bottom or top foot; the minimum at an intermediate depth.

The temperature of the grain in each bin was reduced to approximately atmospheric temperature in about 4 hours of power ventilation. After that, grain temperatures followed the trend of atmospheric temperatures.

These tests were carried on during a period of generally favorable weather for drying. Moisture content of grain was reduced 3.5 percent (from 15.8 to 12.3 percent, bin 4-1) by 147 hours of power ventilation. In the 1942 tests under more humid conditions 1,169 hours of ventilation were required to effect 2.6 percent reduction in moisture; however, this was in twice as much grain per bin as in the 1944 tests. There was no direct comparison of the drying of 4-foot and 8-foot depths of grain in these tests, but the 1944 results yield some information as to desirable depth of grain. When ventilation was ended on November 1, 1944, the

TABLE 4.—*Results of grain sorghum tests started in March and April 1939*¹

Bin No.	Description ²	Quantity of grain <i>Bushels</i>	Filling data			Emptying data				Condition of final sample
			Date	Mois- ture <i>Percent</i>	Grain sorghum ³ grade	Date	Mois- ture <i>Percent</i>	Grain sorghum ³ grade	Grade factor ⁴	
1...	Perforated floor over tight chamber. ²	500	Mar. 20	13.9	No. 1 Y. M.	Oct. 30	12.0	No. 1 Y. M.	.....	Natural odor. ⁵
7...	Floor and wall perforated, east central perforated chamber connected to pressure cowl.	1,000	do ...	13.9	do	Oct. 27	9.5	do .....	.....	Good.
11...	Tight wood bin, insulated.	100	Mar. 25	11.9	.....	Nov. 13	10.5	do .....	.....	Do.
43...	Wall perforated, central vertical perforated tube connected to suction cowl.	500	Mar. 23	13.9	.....	Oct. 31	9.6	do .....	.....	Small musty pockets near floor.
27...	Small bin.	20	Apr. 1	11.7	.....	do	11.3	do .....	.....	Good.
28...	do	20	do	14.0	.....	do	11.4	do .....	.....	Slightly musty.
30...	Small bin insulated with 4-inch glass wool.	20	do	17.0	.....	Nov. 3 Aug. 31 ⁶	13.8	Sample Y. M.	Musty	Spoiled in short time.
31...	do	20	do	14.0	.....	Oct. 31	11.6	No. 1 Y. M., Weevily	Weevily	Slightly musty.
33...	Small bin; 2-inch diameter perforated flues horizontal, spaced 12 inches on centers, ends exposed to atmosphere.	20	do	17.0	.....	Nov. 3	9.6	No. 1 Y. M.	.....	Good.

¹ See also table 5.² All tight cylindrical steel bins except as noted.³ Y. M. = Yellow milo.⁴ Cause of low grade.⁵ On August 31, 1939, a slightly sour odor was observed in samples from central part of this bin. The air chamber under floor was then opened to the outside air.⁶ Date of last sampling.

grain in the upper part of the 4-foot layer still contained 14.8 percent moisture while the bottom part was down to 10 percent moisture. If there had been another 4 feet of grain on top of this, it seems obvious that the upper 4 feet of grain would have contained more than 14.8 percent moisture at this time. Additional favorable weather was not available to have complete drying before winter.

The grain was held in these bins until March 1946. When emptied, no spoilage was found in bin 4-1; 15 bushels of moldy grain was found spread uniformly over the floor in bin 4-2; and 5 bushels of moldy but not caked grain was found over most of the floor in bin 4-3.

TABLE 5.—*Changes in average moisture content of grain sorghum, grade No. 1 Yellow Milo, in storage tests started in March and April 1939 in two ventilated bins and one unventilated bin*¹

Bin No.	Description	Date	Moisture
1...	500-bushel tight steel bin except perforated floor over tight chamber, no ventilation, chamber under floor opened to outside air Sept. 1, 1939.	March 20	13.9
		May 27	13.7
		June 30	13.7
		Aug. 1	12.5
		Aug. 31 ²	12.6
		Sept. 26	12.2
7...	1,000-bushel, perforated wall (east half covered), central chamber 4 by 4 by 2 feet connected to 10-inch pressure cowl.	March 29	13.7
		June 30	10.5
		Aug. 2	9.4
		Sept. 1	9.7
		Nov. 2	9.4
43...	500-bushel, perforated wall, central perforated tube connected to suction cowl.	Apr. 1	13.4
		May 29	12.3
		Aug. 1	11.1
		Sept. 1	10.6
		Nov. 1	9.6

¹ See also table 4.

² Sampler observed slightly sour odor in samples from central part of bin.

TABLE 6.—Filling data on grain sorghum storage tests started in November 1939¹

Bin No.	Description ²	Date filled	Quantity of grain <i>Bushels</i>	Depth of grain <i>Feet</i>	Year grown	Moisture <i>Percent</i>	Grain sorghum grade ³	Grade factor ⁴
1	Perforated floor over tight chamber, no ventilator.....	Nov. 21	480	7.5	1939	15.2	No. 3 Y. M.	Moisture.
2	9-inch pressure cowl connected to conical perforated chamber over center of floor.....	Nov. 23	400	7.0	1939	17.0	No. 4 Y. M.	Do.
7	10-inch pressure cowl connected to central perforated chamber 4 by 4 by 2 feet, perforated walls covered inside with paper.....	Nov. 10	1,000	8.0	1938	17.3	.... do	Do.
11	Wood bin, insulated, perforated metal floor, 10-inch suction cowl on roof.....	Nov. 18	90	5.8	1938	19.9	Sample Y. M.	Musty.
43	20-inch pressure cowl to central perforated tube, perforated walls.....	Nov. 20	450	6.0	1939	17.2	No. 4 Y. M.	Moisture.
46	Perforated floor, centrifugal suction ventilator in roof.....	Nov. 9	975	8.0	1938	17.3	.... do	Do.
24	Tight bin used as check on bin No. 1.....	Nov. 22	20	.....	1939	14.8	No. 2 Y. M.	Do.
27	Tight bin used as check on bin No. 11.....	Nov. 21	20	.....	1938	19.3	Sample Y. M.	Musty.
28	Tight bin used as check on bins 7 and 16.....	Nov. 10	20	.....	1938	16.5	No. 4 Y. M.	Moisture.
30	Tight bin, insulated, used as check on bins 7 and 46.....	Nov. 20	25	.....	1938	17.2	.... do	Do.
31	Tight bin, insulated, used as check on bins 2 and 43.....	Nov. 9	30	.....	1939	16.8	.... do	Do.

¹ See also tables 7 and 8.³ Y. M. = Yellow milo.² All tight cylindrical steel bins except as noted.⁴ Cause of low grade.

TABLE 7.—Storage data on grain sorghum tests started in November 1939¹
[See comments on this table, p. 281]

Bin No.	Notes on operation	Date emptied	Moisture Percent	Grain sorghum grade ²			Grade factor ³	Condition of grain
				No. 3	Y.	M.		
1...	Ventilated with power blower July 8-25, 1940	Oct. 28, 1940	12.2	No.	3	Y. M.	FM	Odor natural, no heat damage.
2...	Average sample on May 2, 1940, was Sample Grade Yellow Milo, Musty.							
7...	Average sample on Aug. 8, 1940, was No. 2 Yellow Milo, odor O.K.	Aug. 6, 1940 ⁴	12.1	No.	2	Y. M.	.. do ..	(⁵)
43...	Unloaded for cleaning, inspection, and to remove paper lining from wall on Apr. 25, 1940	Aug. 7, 1940 ^{5,6}	11.7	Sample	Y.	M.	Musty	Odor natural, no heat damage.
		Oct. 26, 1940	11.2	No.	3	Y. M.	FM	Odor natural, no heat damage.
46...	Ventilated with power blower; unloaded and cleaned Apr. 11, 1940.	Oct. 28, 1940	12.4	Sample	Y.	M.	Musty	Odor natural, no heat damage.
24...	None	Feb. 3, 1941 ⁴	14.7	....	do	....	do ..	....
27...	.... do	May 2, 1940 ⁴	15.8	....	do	....	Musty, 48 per-cent	Very moldy.
28...	.... do	Feb. 3, 1941 ⁴	16.4	....	do	....	damage Musty, 22 per-cent	White mold on all kernels.
30...	.... do .....	.... do	15.9	....	do	....	damage Musty	Do.
31...	.... do .....	.... do	16.6	....	do	....	Musty, 40 per-damage	Do.

¹ See also tables 6 and 8.² Y. M. = Yellow Milo.³ Cause of low grade; FM = cracked grain and foreign material.⁴ Date of last sampling of year.⁵ When inspected May 6, 1940, molded and caked grain were found in locations in the bin where cracked grain and foreign material accumulated when the bin was filled. Figures 9 and 10 are close-up photographs showing damaged and undamaged grain in this bin.⁶ Grain held over until October 1941; see next year's report, tables 9 and 10.

TABLE 8.—*Changes in average moisture content of grain in storage tests started in November 1939*¹

Date (1940)	Moisture in bin No.—				
	1	2	7	43	46
	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Initial	15.2	17.0	17.3	17.2	17.3
Jan. 30	15.5	16.3	16.8	15.8	16.7
Mar. 7	15.1	16.5	15.8	16.1	16.9
Apr. 10	15.2	15.9	15.3	15.4	16.8
May 3	15.0	15.8	14.9	14.5	16.1
June 1	15.4	13.6	13.2	13.0	² 13.3
28	15.2	13.3	12.7	12.4	13.2
Aug. 7	² 12.5	12.1	11.7	11.0	12.9
Nov. 4	12.2	...	...	11.2	12.4

¹ See also tables 6 and 7.² Ventilated with power blower since previous sampling.TABLE 9.—*Filling data on grain sorghum storage tests started in November 1940*

[See comments on this table, p. 29]

Bin No.	Description ¹	Date filled	Quantity of grain	Depth of grain	Moisture	Grain sorghum grade ²	Grade factor ³
			<i>Bushels</i>	<i>Feet</i>	<i>Percent</i>		
1...	Perforated floor over tight chamber, no ventilation.	Nov. 7, 1940	500	7.5	15.8	Sample Y. M.	Sour.
7...	10-inch pressure cowl connected to 4 by 4 by 2 feet central perforated air chamber, perforated floor, perforated wall after April 1940.	Nov. 10, 1939	1,000	8.0	17.3	No. 4 Y. M.	Moisture.
43...	Perforated wall, central vertical perforated 18-inch flue open at top and bottom, but not connected to any ventilator, floor perforated near wall.	Nov. 5, 1940	500	7.0	15.1	Sample Y. M.	Sour.
46...	Perforated floor over tight chamber connected to 9-inch pressure cowl, centrifugal suction ventilator in roof.	Nov. 9, 1940	1,000	7.5	15.3	...do...	Do.
47...	Pressure cowl to central perforated air chamber, perforated floor and walls.	Nov. 7, 1940	1,000	8.0	15.5	...do...	Do.

¹ All tight cylindrical steel bins except as noted.² Y. M. = Yellow milo.³ Cause of grade being low.

TABLE 10.—*Changes in grain sorghum in storage tests started in November 1940*¹

[See comments on this table, p. 291]

Date	Bin No. 1				Bin No. 7 ²				Bin No. 43				Bin No. 46				Bin No. 47			
	Mois- ture	Grain sorghum grade ³	Grade factor ⁴		Mois- ture	Grain sorghum grade ³	Grade factor ⁴		Mois- ture	Grain sorghum grade ³	Grade factor ⁴		Mois- ture	Grain sorghum grade ³	Grade factor ⁴		Mois- ture	Grain sorghum grade ³	Grade factor ⁴	
Initial	Percent 15.8	Sample Y. M.	Sour		Percent 11.7	No. 1 Y. M.	. . . . .		Percent 15.1	Sample Y. M.	Sour		Percent 15.3	Sample Y. M.	Sour		Percent 15.5	Sample Y. M.	Sour	
Dec. 28, 1940	16.1	. . do . .	. . do . .		. . . . .	. . do . .	. . . . .		15.3	. . do . .	. . do . .		15.5	. . do . .	. . do . .		15.6	. . do . .	Do.	
Mar. 12, 1941	. . . . .	. . do . .	. . . . .		12.6	. . do . .	. . . . .		14.8	. . do . .	Musty		15.4	. . do . .	Musty		15.5	. . do . .	Musty.	
June 28, 1941	16.3	. . do . .	Musty		. . . . .	. . do . .	. . . . .		14.6	. . do . .	. . do . .		. . . . .	. . do . .	. . do . .		14.3	. . do . .	Do.	
Aug. 19, 1941	. . . . .	. . do . .	. . do . .		. . . . .	. . do . .	. . . . .		. . . . .	. . do . .	. . do . .		. . . . .	. . do . .	Musty		. . . . .	. . do . .	Do.	
Oct. 17, 1941	. . . . .	. . . . .	. . . . .		12.1	. . do . .	. . . . .		11.6	No. 2 Y. M.	TW, FM		12.3	No. 2 Y. M.	TW		12.2	No. 2 Y. M.	TW	

¹ See also table 9.² All bins, except No. 7, were fumigated in June 1941, and all were fumigated in October 1941.³ Y. M. = Yellow milo.⁴ Cause of low grade; TW = test weight; FM = cracked grain and foreign material.⁵ Sample taken June 17, 1941

TABLE 11.—*Moisture in grain, grain temperature, and grade factors in sorghum stored in power-ventilated bins, 1942*¹

[See comments on this table, p. 30]

MOISTURE IN GRAIN

Sampling date	Sampling location ²	Bin No. —				
		1/2-14	3-2	4-1	4-2	4-3
Initial .....	.....	Percent 12.8	Percent 15.2	Percent 14.8	Percent 20.0	Percent 13.6
Feb. 13 .....	.....	.....	.....	.....	17.1	.....
May 5	6-8 .....	.....	14.6	14.1	.....	.....
	4-6 .....	.....	15.5	14.9	.....	13.2
	2-4 .....	.....	15.2	15.5	.....	13.3
	0-2 .....	.....	15.2	15.6	.....	13.7
	Bin average ..	.....	15.1	15.0	.....	13.7
June 9	6-8 .....	.....	15.4	15.1	13.1	.....
	4-6 .....	.....	15.5	15.7	.....	13.7
	2-4 .....	.....	15.6	15.5	.....	12.9
	0-2 .....	.....	14.6	13.1	12.8	11.9
	Bin average ..	12.8	15.3	14.4	13.0	12.8
June 27	Bin average ..	.....	13.8	.....	.....	.....
July 2	do .....	.....	13.9	13.3	.....	.....
29	do .....	.....	³ 12.6	.....	.....	.....
29	do .....	.....	³ 12.3	.....	.....	.....
Aug. 17	do	12.9	12.2	.....	.....	12.9
Sept. 18	do	12.8	12.0	.....	.....	12.4

AVERAGE TEMPERATURE OF GRAIN

		°F.	°F.	°F.	°F.	°F.
Jan. 5	Bin average ..	.....	47	46	21	.....
Apr. 18	do	55	53	52	53	.....
May 16	do	59	62	61	60	64
27	do	64	76	78	.....	82
June 16	do	69	71	70	.....	67
July 8	do	74	.....	.....	.....	80
Aug. 14	do	83	.....	.....	.....	85

¹ See also table 13. Bin 1/2-14 was filled on April 13, 1942; bin 3-2 on Dec. 16, 1941; bin 4-1 on Dec. 10, 1941; bin 4-2 on Dec. 27, 1941; and bin 4-3 on Apr. 17, 1942.

² Designation, such as 6-8, is distance above floor in feet, average of bin at that level.

³ Grain moved from bin 3-2 to tight bin 1/2-3 on this date, sampled before and after moving.

TABLE 11.—*Moisture in grain, grain temperature, and grade factors in sorghum stored in power-ventilated bins, 1942—Continued*

GRADE FACTORS

Bin No. and sampling date	Grain sorghum grade ⁴	Test weight	Mois- ture	Dock- age	Odor	Total damage	Foreign material, etc.	Fat acid- ity	Germi- nation
3-2:		Pounds	Percent	Percent		Percent	Percent	Units	Percent
Dec. 18, 1941	No. 3 Y. M. Disc.	54.4	15.2	0.1	O. K.	3.7	1.5	30	63
May 6, 1942	do	53.8	15.1	.2	do	1.0	2.2	33	56
June 9, 1942	Sample Y. M. Disc.	54.3	15.3	.3	Musty	2.0	1.8	39	.....
July 29, 1942	do	55.3	12.6	1.4	do	1.6	3.2	.....	.....
Sept. 18, 1942	No. 2 Y. M. Weevily	54.2	12.0	.4	O. K.	1.0	2.4	.....	.....
Dec. 11, 1941	No. 2 Y. M. Disc.	55.0	14.8	.1	do	2.7	1.0	30	58
4-1:									
May 2, 1942	Sample Y. M. Disc.	54.6	15.0	.1	Musty	1.7	1.0	34	42
June 9, 1942	do	54.5	14.8	.1	do	1.2	1.1	39	.....
Do	No. 2 Y. M. Disc.	55.0	14.4	.1	O. K.	1.2	.9	40	.....
4-2:									
Do	Sample Y. M. Disc.	49.1	13.0	.8	Musty	8.5	6.6	105	1.0
4-3:									
Apr. 17, 1942	No. 2	54.4	13.6	.8	O. K.	.4	7.6	32	.....
May 2, 1942	Mixed	53.2	13.6	.4	do	1.4	8.0	41	58
June 9, 1942	do	53.7	12.8	.7	do	1.0	7.0	43	.....
Aug. 17, 1942	No. 2 Mixed Weevily	54.7	12.4	.5	do	.5	6.8	.....	.....

⁴ Y. M. = Yellow milo.TABLE 12.—*Moisture content, average temperature, and grade factors in grain sorghum in wind-ventilated bins, 1942-43* ¹

[See comments on this table, p. 32]

MOISTURE IN GRAIN

Sampling date	Sampling location ¹	Bin No. — ²					
		1/2-14	2-17	3-16	1/2-16	1/2-15	1/2-4
Apr. 13-20, 1942	Bin average ..	Percent 12.8	Percent 12.8	Percent 13.1	Percent 12.5	Percent 12.8	Percent 13.6
	{ 6-7 .....	...	12.4	12.7	12.1	12.7	13.1
	{ 3-4 .....	...	13.0	13.1	12.0	12.6	14.0
June 10-19, 1942	{ 0-1 .....	...	12.9	13.4	12.0	12.8	14.3
	{ Bin average ..	12.8	12.9	13.1	12.1	12.8	13.9

See footnotes at end of table.

TABLE 12.—*Moisture content, average temperature, and grade factors in grain sorghum in wind-ventilated bins, 1942-43*¹—Continued

[See comments on this table, p. 32]

MOISTURE IN GRAIN

Sampling date	Sampling location ²	Bin No. — ²					
		2-17	1/2-14	3-16	1/2-16	1/2-15	1/2-4
		Percent	Percent	Percent	Percent	Percent	Percent
Aug. 15 to Sept. 9, 1942..	6-7 .....	...	12.0	12.3	12.3	13.1	12.7
	3-4 .....	...	12.2	12.2	13.5	13.0	13.9
	0-1 .....	...	13.0	13.1	14.2	12.9	14.1
	Bin average ..	12.9	12.3	12.3	13.3	12.9	13.8
Sept. 18, 1942	do	12.8	12.6	12.3	13.0	12.4	13.1
Feb. 8, 9, 1943	do	12.9	12.2	12.0	12.6	12.3	12.8

AVERAGE TEMPERATURE OF GRAIN

1942		°F.	°F.	°F.	°F.	°F.	°F.
Apr. 13-23	Bin average ..	55	...	58	...	56	...
May 13-19	do	59	64	63	58	...	61
May 25-29	do	64	73	71	71	...	66
June 10-22	do	69	...	70	...	77	...
July 8-9	do	74	79	80	81	77	89
Aug. 1-6	do	77	79	85	82	84	80
Aug. 10-17	do	83	80	84	89	93	82
Aug. 26-31	do	82	82	84	87	89	84
Sept. 10	do	81	83	90	...	89	79
Sept. 23	do	76	68	69	...	84	70
Oct. 8	do	71	64	64	...	73	65

GRADE FACTORS

Bin number and sampling date	Grain sorghum grade ³	Test weight	Moisture	Dock-age	Odor	Total damage	Foreign material ⁴	Fat acidity	Germination
		Pounds	Percent	Percent		Percent	Percent	Units	Percent
1/2-14:									
Apr. 15, 1942	No. 3 Mixed	52.0	12.8	0.8	O. K.	0.4	4.6	31	63
Feb. 9, 1943	do	51.6	12.9	.8	do ..	.5	5.0	51	29
2-17:									
Apr. 15, 1942	do	52.2	12.8	1.6	do ..	.4	5.9	36	63
Feb. 8, 1943	do	52.4	12.2	.7	do ..	.4	5.0	53	28
3-16:									
Apr. 15, 1942	No. 2 Mixed	53.2	13.1	.8	do ..	.4	5.4	35	55
Feb. 8, 1943	do	53.2	12.0	.9	do ..	.5	6.0	53	27
1/2-16:									
Apr. 9, 1942	No. 2 Y. M.	54.3	12.5	.6	do ..	.2	4.4	31	63
Feb. 8, 1943	do	54.9	12.6	1.9	do ..	.4	5.5	55	6
1/2-15:									
Apr. 15, 1942	No. 3 Mixed	52.8	12.8	.8	do ..	.4	4.2	37	55
Feb. 8, 1943	No. 2 Mixed	53.4	12.3	.4	do ..	.4	5.0	58	16
1/2-4:									
Apr. 20, 1942	No. 3 Mixed	54.3	13.6	1.0	do ..	.5	8.2	31	61
Feb. 9, 1943	do	54.5	12.8	.9	do ..	.4	9.0	56	21

¹ Designations, as 6-7, indicate distance above floor in feet, average of bin at that level.² Bins 1/2-14, 2-17, and 3-16 filled on Apr. 13, bins 1/2-16 and 1/2-15 filled Apr. 8, and bin 1/2-4 filled Apr. 17, 1942.³ Y. M. = Yellow milo.⁴ Includes cracked grain.

TABLE 13.—*Blower schedule on grain sorghum power-ventilated bins, May 13 to July 22, 1942, bins 3-2, 4-1, 4-2, and 4-3*¹

Date	Blower operation		Total time	
	Start	Stop	Hours	Minutes
May 13	2:15 p.m.	8:15 p.m.	6	..
14	2:15 p.m.	9:15 p.m.	7	..
15	11:00 a.m.	7:15 p.m.	8	15
16	11:30 a.m.	4:30 p.m.	5	..
17	Blower off .....	.....	..	..
18	2:00 p.m.	4:30 p.m.	2	30
19	10:30 a.m.	7:30 p.m.	9	..
20-25 ² .....	.....	.....	..	..
26	10:00 a.m.	8:00 p.m.	10	..
27	3:00 p.m.	8:30 p.m.	5	30
28	10:00 a.m.	9:15 p.m.	11	15
29	11:00 a.m.	8:00 p.m.	9	..
30	10:00 a.m.	8:00 p.m.	10	..
31	8:00 a.m.	8:00 p.m.	12	..
June 1	8:00 a.m.	8:00 p.m.	12	..
2	8:00 a.m.	8:00 p.m.	12	..
3	8:00 a.m.	8:00 p.m.	12	..
4	8:00 a.m.	8:00 p.m.	12	..
5	8:00 a.m.	8:00 p.m.	12	..
6 ³	⁴ 8:00 a.m. ....	.....	..	..
July 10 .....	.....	3:00 p.m.	823	..
14	⁴ 3:00 p.m. ....	.....	..	..
22 .....	.....	2:00 p.m.	191	..
Total .....	.....	.....	1,169	30

¹ See also table 11.² Relative humidity not suitable for ventilation.³ Bin 4-3 not ventilated after June 6.⁴ Blower operated continuously from time of start until time indicated in next line.

TABLE 14.—Average and maximum temperatures in grain storage wind-ventilated bins, 1944-45¹

Date	Temperatures in—					
	Bin No. 1			Bin No. 2		
	Average	Maximum	Location ²	Average	Maximum	Location ²
<i>1944</i>						
Sept. 19.....	80.00	95	SW-4.....	°F.	°F.	
22.....	78.11	92	SW-4.....			
26.....	71.00	75	SW-4.....			
Oct. 2.....	66.46	71	SW-4.....			
10.....	62.40	69	C-4.....			
14.....	55.25	63	C-4.....	55.85	63	SW-F
18.....	60.65	66	SE-4.....	60.25	69	SW-2½
26.....	58.58	62	SE-4.....	59.60	65	SW-4
Nov. 3.....	65.95	73	SE-F.....	64.10	74	SE-F
10.....	58.00	63	C-4.....	60.55	64	C-F
24.....	47.00	51	SE-F.....	47.00	49	SE-2½
Dec. 7.....	46.11	62	SE-F.....	39.00	43	SE-F
21.....	45.73	57	NE-F.....	42.25	47	SE-F
<i>1945</i>						
Jan. 9.....	41.84	50	SE-F.....	38.15	46	SW-4
Feb. 2.....	40.89	45	C-2½.....	38.40	44	C-2½
Mar. 1.....	40.26	47	SE-F.....	38.05	43	C-2½
29.....	58.57	63	NE-1.....	57.60	63	SW-4
Apr. 18.....	52.85	57	SE-1.....	53.60	57	C-2½
May 4.....	60.80	73	NE-F.....	58.80	61	SE-F
23.....	63.30	68	NE-4.....	59.75	62	SE-4
June 11.....	65.45	68	SE-2½.....	67.20	70	NE-4
25.....	72.35	78	SE-2½.....	72.65	77	SE-4
July 11.....	73.40	79	SW-2½.....	77.20	85	NE-4
25.....	89.63	105	N-F.....	87.20	94	NE-4
Aug. 4.....	82.84	86	S-3.....	89.75	104	C-2½
7.....	84.05	88	S-2.....	89.35	106	C-2½
18.....	78.65	81	S-3.....	84.50	96	C-2½
22.....	80.60	87	S-2.....	83.90	97	C-2
28.....	81.15	91	E-3.....	82.35	87	C-2
Oct. 5.....	61.40	67	S-1.....	58.55	62	C-2
<i>1946</i>						
Jan. 11.....	46.75	50	S-2.....	39.35	43	E-2

¹The wind pressure cone was removed from bin No. 2 from November 22, 1944, to August 11, 1945. For changes in grain moisture, see figure 15.

²C = Center of bin; corner locations (NE, SE, SW, and NW) are 1 foot from side wall and 3 feet from end wall; last letter or figure designates floor or distance above floor in feet.

TABLE 15.—*Changes in grain moisture content, temperature, and grade factors in power-ventilated bins, 1944*¹

[See comment on this table, p. 33]

MOISTURE IN GRAIN

Date	Bin No. 4-1			Bin No. 4-2			Bin No. 4-3		
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
<i>1944</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Sept. 16.....	15.8	16.2	15.1	15.8	16.0	15.6	15.4	16.0	15.0
18.....	15.2	15.4	14.9	15.2	15.9	14.6	15.3	15.8	14.2
20.....	14.4	15.3	13.1	14.9	15.8	12.3	14.9	16.2	12.7
25.....	14.0	15.2	10.0	13.8	15.8	10.7	14.1	15.8	9.9
Oct. 16.....	13.5	15.1	10.7	13.3	15.7	10.4	13.4	15.8	10.5
20.....	13.2	15.0	10.4	12.8	15.6	10.2	13.3	15.7	10.0
26.....	12.6	14.5	9.9	12.1	14.9	10.0	12.2	14.9	9.7
Nov. 1.....	12.3	14.6	10.0	12.0	14.8	10.0	11.9	14.8	9.6
10.....	12.1	14.4	9.8	11.8	14.6	10.0	11.6	14.3	9.7
<i>1945</i>									
Jan. 10.....	12.3	14.7	10.9	11.8	14.8	10.4	11.8	14.9	10.2
<i>1946</i>									
Mar. 20.....	12.7	13.8	12.3	12.4	13.4	11.6	12.3	13.7	11.5

GRAIN TEMPERATURE²

1944		°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
Sept.	16.....	92	.....	.....	76	.....	.....	74	.....
	18.....	75	.....	.....	73	.....	.....	74	.....
	20.....	79	.....	.....	78	.....	.....	79	.....
Oct.	5.....	66	.....	.....	64	.....	.....	66	.....
	14.....	64	.....	.....	62	.....	.....	62	.....
	18.....	64	.....	.....	65	.....	.....	67	.....
	26.....	64	.....	.....	66	.....	.....	65	.....
Nov.	3.....	71	.....	.....	71	.....	.....	72	.....
	9.....	63	.....	.....	64	.....	.....	63	.....

GRADE FACTORS

Date	Bin No.	Grain sorghum grade	Test weight	Moisture	Dock-age	Odor	Total damage	Foreign material ³	Fat acidity	Germination
<i>1944</i>	4-1	Sample Y. M. ⁴	<i>Pounds</i>	<i>Percent</i>	<i>Percent</i>		<i>Percent</i>	<i>Percent</i>	<i>Unit</i>	<i>Percent</i>
			57.5	14.0	0.3	Sour	.....	4.9	50	39
Oct. 2 ⁵	4-2	... do ...	57.0	13.8	.5	... do ...	.....	4.6	58	40
	4-3	... do ...	57.0	13.9	.1	... do ...	.....	3.8	47	39

¹ See also table 16.² Temperatures given are bin averages.³ Includes cracked grain.⁴ Y. M. = Yellow milo.⁵ No other samples taken.

TABLE 16.—*Schedule of blower operation, bins 4-1, 4-2, and 4-3, in 1944 tests*¹

Date	Blower operation			Approximate relative humidity	Water pressure		
	Start	Stop	Total time				
			Hours	Minutes	Percent	Inches	
Sept. 16 ²	8:00 a.m..	6:00 p.m..	10	0	.....	(³)	
	17.....	11:30 a.m..	3:00 p.m..	3	30	.....	(³)
	18.....	8:00 a.m..	5:00 p.m..	9	0	.....	(³)
	19.....	8:00 a.m..	8:00 p.m..	12	0	50	(³)
	20.....	8:00 a.m..	6:00 p.m..	10	0	40	(³)
	21.....	8:50 a.m..	9:10 p.m..	12	20	30	(³)
	22.....	7:45 a.m..	9:45 p.m..	14	0	30	(³)
	24.....	11:30 a.m..	6:00 p.m..	6	30	50	(³)
Oct. 14.....	11:00 a.m..	4:45 p.m..	5	45	40	0.75	
	16.....	1:30 p.m..	5:00 p.m..	3	30	35	.75
	17.....	11:30 a.m..	4:45 p.m..	5	15	40	.75
	20.....	2:00 p.m..	4:45 p.m..	2	45	32	.75
	23.....	11:30 a.m..	4:45 p.m..	5	15	38	.75
	24.....	10:00 a.m..	4:45 p.m..	6	45	40	.75
	25.....	10:30 a.m..	4:45 p.m..	6	15	38	.75
	26.....	10:00 a.m..	4:45 p.m..	6	45	38	.8
	27.....	10:00 a.m..	4:30 p.m..	6	30	30	.8
	28.....	11:15 a.m..	4:45 p.m..	5	30	40	.8
	30.....	11:00 a.m..	4:45 p.m..	5	45	40	.8
Nov. 31.....	11:30 a.m..	4:45 p.m..	5	15	40	.8	
	1.....	12:00 noon	4:45 p.m..	4	45	40	.8
Total....	.....	.....	147	20	.....	.....

¹ See table 15.² Bin 4-1 not filled on this date.³ Air pressure during this period: 4-1, 0.6 inch; 4-2, 1.3 inches; 4-3, 0.75 inch. Rate of drying was not perceptibly affected by this difference in pressure.TABLE 17.—*Chemical analyses for feeding values of silage made from sorghum grain (Yellow milo) of various moisture contents, May 1945*¹

Item	Laboratory number and composition					
	Silage from sorghum grain at indicated moisture content					
	(M-3115) Original sorghum grain	(M-3116) Cracked grain, 17 per- cent moisture	(M-3117) Whole grain, 19 per- cent moisture	(M-3118) Whole grain, 21 per- cent moisture	(M-3119) Whole grain, 30 per- cent moisture	(M-3120) Whole grain, 39 per- cent moisture
	Percent	Percent	Percent	Percent	Percent	Percent
Protein	15.96	16.29	16.03	16.04	16.02	15.99
Ether extract (fat) ...	3.38	2.49	3.31	3.34	3.39	3.30
Crude fiber	2.54	2.67	2.39	2.47	2.35	3.04
Ash	2.08	5.14	5.10	5.87	6.01	6.33
Total	23.96	26.59	26.83	27.72	27.77	28.66
Nitrogen-free extract ² ..	76.04	73.41	73.17	72.28	72.23	71.34
pH	6.40	6.21	6.42	6.38	4.56	4.75
Moisture in sample analyzed	13.05	20.44	17.95	20.82	38.38	41.45

¹ On moisture-free basis.² Determined by difference.

TABLE 18.—*Insect population in grain sorghum of different moisture contents on different dates at Hutchinson, Kans., 1946*

Date	Insects ¹	Insects in a 1,000-gram sample of grain with moisture content indicated			
		10 per cent	12 per cent	12.5 per cent	15 per cent
		Number	Number	Number	Number
Jan. 2....	{ Weevils.....	0	0	0	0
	{ Bran beetles...	0	0	0	0
Apr. 6....	{ Weevils.....	0	0	0	0
	{ Bran beetles...	0	0	0	0
May 4....	{ Weevils.....	0	0	0	0
	{ Bran beetles...	.4	0	0	0
June 11....	{ Weevils.....	.2	0	.3	.1
	{ Bran beetles...	.2	.4	.9	0
July 1....	{ Weevils.....	3.3	.1	2.1	.3
	{ Bran beetles...	1.4	3.3	1.9	1.7
July 15....	{ Weevils.....	5.2	5.7	13.7	4.6
	{ Bran beetles...	6.7	9.4	7.0	10.4
July 26....	{ Weevils.....	5.7	9.7	14.0	4.9
	{ Bran beetles...	14.9	14.7	16.9	10.6

¹ Weevils include only the lesser grain borer (*Rhyzopertha dominica* (F.)) no other species classed as weevils were observed. Bran beetles includes all other species; these were the flat grain beetle (*Laemophloeus minutus* (Oliv.)), saw-toothed grain beetle (*Oryzaephilus surinamensis* (L.)), long-headed flour beetle (*Latheticus oryzae* Waterh.), red flour beetle (*Tribolium castaneum* (Hbst.)), and hairy fungus beetle (*Typhaea stercorea* (L.)).

TABLE 19.—*Location of insect infestation in grain sorghum of different moisture contents stored in 1,000-bushel steel bins, Hutchinson, Kans., 1946*¹

Location from which sample was taken	Percentage of total number of insects taken from grain sorghum (average of two bins) of indicated moisture contents				
	10.5 percent	12.0 percent	12.5 percent	15 percent	Average of 8 bins
	Percent	Percent	Percent	Percent	Percent
Surface	26.9	30.9	20.7	50.0	30.3
Center	4.9	6.9	7.6	12.7	7.8
North	2.3	9.5	12.4	9.7	8.9
East	16.3	13.2	7.8	3.5	10.4
South	16.7	7.2	13.9	10.1	12.1
Southwest	17.8	19.7	15.1	6.6	15.3
West	15.2	12.5	22.7	7.5	15.5
Mean	22.1	25.5	33.3	19.1	.....

¹ Total number of insects observed, 2,386.

TABLE 20.—*Fluctuation of population of species of insects in grain sorghum stored in 1,000-bushel steel bins, Hutchinson, Kans., 1946*

BINS 2-16, 3-15 (10 PERCENT MOISTURE)

Date	Insects per 1,000 grams ¹	Species of insect					
		Lesser grain borer	Flat grain beetle	Saw- toothed grain beetle	Long- headed flour beetle	Red flour beetle	Hairy fungus beetle
	<i>Number</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Jan. 2.....	0	.....	.....	.....	.....	.....	.....
Apr. 6.....	0	.....	.....	.....	.....	.....	.....
May 4.....	.4	.....	.....	.....	.....	100.0	.....
June 11.....	.4	50.0	.....	50.0	.....	.....	.....
July 1.....	4.7	69.7	3.0	12.1	.....	15.2	.....
15.....	11.9	43.4	3.6	47.0	.....	6.0	.....
26.....	20.6	27.8	6.3	62.5	.....	3.5	.....
Pct. of total	.....	38.87	4.92	50.75	.....	6.44	.....

BINS 3-14, 4-13 (12 PERCENT MOISTURE)

Jan. 2.....	0	.....	.....	.....	.....	.....	.....
Apr. 6.....	0	.....	.....	.....	.....	.....	.....
May 4.....	0	.....	.....	.....	.....	.....	.....
June 11.....	.4	.....	.....	66.7	.....	33.3	.....
July 1.....	3.4	4.2	4.2	83.3	.....	8.3	.....
15.....	15.1	37.7	12.3	43.4	.....	6.6	.....
26.....	24.4	39.8	2.9	56.1	.....	1.2	.....
Pct. of total	.....	36.09	6.25	53.95	.....	3.95	.....

BINS 2-12, 2-14 (12.5 PERCENT MOISTURE)

Jan. 2.....	0	.....	.....	.....	.....	.....	.....
Apr. 6.....	0	.....	.....	.....	.....	.....	.....
May 4.....	0	.....	.....	.....	.....	.....	.....
June 11.....	1.2	25.0	25.0	37.5	.....	12.5	.....
July 1.....	4.0	53.6	10.7	14.3	.....	21.4	.....
15.....	20.7	66.2	3.4	25.6	.....	4.8	.....
26.....	30.9	45.4	6.5	38.0	0.5	9.7	.....
Pct. of total	.....	53.15	6.05	31.73	.25	8.82	.....

BINS 1-7, 1-16 (15 PERCENT MOISTURE)

Jan. 2.....	0	.....	.....	.....	.....	.....	.....
Apr. 6.....	0	.....	.....	.....	.....	.....	.....
May 4.....	0	.....	.....	.....	.....	.....	.....
June 11.....	.1	100.0	.....	.....	.....	.....	.....
July 1.....	2.0	14.3	78.6	.....	.....	7.1	.....
15.....	15.0	30.5	61.0	6.7	.....	1.0	1.0
26.....	15.5	31.5	64.8	2.8	.....	.9	.....
Pct. of total	30.26	63.60	4.39	1.32	.44
Pct., all bins	40.99	16.85	36.38	.08	5.62	.08

¹ Average of 2 bins.

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